Contract 3436/B2015/RO-GIO/EEA.56166. Negotiated procedure No EEA/IDM/15/009 based on Article 5 of Regulation (EC) No 401/2009 of 23.4.2009 on the European Environment Agency and the European Environment Information and Observation Network

Task 1.9 - Analysis of the LUCAS nomenclature and proposal for adaptation of the nomenclature in view of its use by the Copernicus land monitoring services

Prepared by:

Oliver Buck, Carsten Haub, Sascha Woditsch, Dirk Lindemann, Luca Kleinewillinghöfer, Gerard Hazeu, Barbara Kosztra, Stefan Kleeschulte, Stephan Arnold, Martin Hölzl

30.11.2015

Version 2.2

European Commission

Europe's eyes on Earth

Implemented by

EEA

Legal notice

The contents of this publication were created by EFTAS and partners under EEA service contract No. 3436/B2015/R0-GIO/EEA.56166 and do not necessarily reflect the official opinions of the European Commission or other institutions of the European Union. Neither the European Environment Agency nor any person or company acting on behalf of the Agency is responsible for the use that may be made of the information contained in this report.

Copyright notice

E F T A S Fernerkundung
Technologietransfer GmbH
Oststraße 2-18, 48145 Münster,

Wageningen UR
Droevendaalsesteeg 3
P.O. Box 47, 6700 AA Wageningen, The Netherlands

Umweltbundesamt Österreich
Spittelauer Lände 5
1090 Vienna/Austria

Földmérési és Távérzékelési Intézet (FÖMI)
Bosnyák tér 5
Budapest
1149 - Hungary

space4environment Sàrl
46, rue Gabriel Lippmann, L-6947 Nieder-anven

Statistisches Bundesamt
Gustav-Stresemann-Ring 11
65189 Wiesbaden

Document control

Authors

	Name	Date	Signature
Author(s)	Buck, Kleinewillinghöfer, Woditsch	30.11.2015	
Reviewer(s)	Haub, Lindemann	01.12.2015	
Approver(s)	Buck	01.12.2015	

Distribution

Organisation	Name	No of copies
EEA	H. Dufourmont, A. Sousa, T. Langanke	1xdigital, 1xanalog
ESTAT	B. Eiselt	1xdigital, 1xanalog
JRC	J. Gallego	1xdigital
DG Grow	C. Bamps	1xdigital
Study partner	Space4environment, FÖMI, DeStatis, EAA, Alterra	1xdigital

Change Record

Release	Date	Description	Editor/Reviewer(s)
2.2.	30.11.15	Follow-up corrections from Meeting in Brussels (12.11.15). • Information on riparian zone nomenclature • Added LC information on grassland and shrub recommendations • Editorial changes (grammar and spell check)	Buck
2.1	30.10.15	Included • Feedback ESTAT (20.10./23.10.15) • Feedback EEA (28/29.10.2015)	Buck
2.0	05.10.2015	Included • Analysis • Recommendations	EFTAS (Buck, Haub, Lindemann, Woditsch) All partners (contribution to matrices
1.4	25.08	Integrated • Feedback FÖMI 17.08.15 • Feedback ESTAT 21.08.15 Editorial changes to • Chapter 1 and 2	Buck
1.3	14.08.	Added • Online survey results • EEA survey summary Finalized chapter 2. Integrated feedback from: • Space4environment 10.08.15 • Alterra 11.08.15 • DeStatis 13.08.15	Buck, Kleinewillinghöfer, Haub
1.2	05.08.	Integration of contribution from	Buck

		• FÖMI 24.07 • Destatis 17.07	
1.1	08.07	Integration of contribution from • space4environment 02.07.15 • Alterra 03.07.15	Buck
1.0		Initial draft for partner circulation	Buck

CONTENT ....PAGE

FIGURES .... **Page**

TABLES .... Page

ABBREVIATIONS

Abbreviation	Description
CAPI	Computer assisted photo interpretation
CLC	Coordination of information on the environment (CORINE) Land Cover
DG	Directorate-General
DTM	Digital terrain model
EC	European Commission
EEA	European Environment Agency
EFTA	European Free Trade Association
ENV	Environment
EO	Earth observation
ESA	European Space Agency
ESS	European Statistical System
ETC	European Topic Centre
EU	European Union
FAD	High resolution layer Forest Additional Support layer
FAO	Food and Agriculture Organization of the United Nations
FTY	High resolution layer Forest Type
GIO	GMES initial operation
GLE	Green linear elements
GMES	Global Monitoring for Environment and Security
HR	High Resolution
HRL	High Resolution Layer
IMD	High resolution layer Degree of Imperviousness
IRS	Indian remote sensing
LC	Land cover
LU	Land use
MAES	Mapping and Assessment of Ecosystems and their services
MMU	Minimum mapping unit
MR	Medium Resolution
MS	Member state
NFP	National focal points
NGR	News grassland layer
NGR	High resolution layer Grassland
NRC	National reference centres
NSI	National Statistics Institutions
NUTS	Nomenclature des unités territoriales statistiques
PWB	High resolution layer Permanent Water Bodies
SIA	Spatial Information and Analysis
SP	Service provider
TCD	High resolution layer Tree cover density

UA	Urban Atlas
ULS	Urban, Land and Soil Systems
UN	United Nations
VHR	Very High Resolution
WET	High resolution layer Wetland

Executive Summary

LUCAS and Copernicus are two European flagship programmes providing information on land cover and land use across Europe. While LUCAS provides statistical data derived from ground surveys, the Copernicus services provides land cover and land use maps across Europe. To improve the suitability of LUCAS data within the Copernicus land monitoring services, the background, intention and components of these programmes have to be assessed. In a first step **a status quo assessment** of LUCAS is presented including background information, links to national statistical application (in the light of Copernicus), project phases, data models as well as expectations by selected users through online surveys. The same structured status quo description was applied to the different Copernicus land monitoring components, including CORINE, the High Resolution Layers and the Copernicus local components Urban Atlas and Riparian Zones.

To identify links between the two programmes **temporal, thematic and spatial aspects were analysed** in-depth. The results showed an **overall good conformity of the different Copernicus nomenclatures to the current LUCAS data model.** Several aspects could be highlighted to improve the future use of LUCAS in Copernicus land monitoring activities, including a lack of knowledge on the use of the full LUCAS data model and required adaptations to the LUCAS data model. **A set of recommendations and actions was worked out to improve the uptake of LUCAS in Copernicus.**

ACTION1:

LUCAS user manuals should be prepared to highlight and explain the use of LUCAS micro data (including the relevant metadata) for Copernicus related validation tasks.

ACTION2:

The LUCAS nomenclature and data model should be revised and adapted to include the identified LC/LU and metadata issues.

ACTION3:

The empirical spatial analysis of LUCAS and Copernicus products should be extended to consolidate the thematic matching of LUCAS LC/LU codes with Copernicus classes.

ACTION4:

The results from this study should be provided to the EAGLE working group to support their work on the semantic translation of Land cover / Land use nomenclatures in Europe.

1 Introduction

The LUCAS and Copernicus programmes are considered to be two flagship products on land cover and land use at European level. The generation and purpose of their output products have completely different principles. The CORINE land cover (CLC) and the High Resolution (HR) layers are components of the Copernicus land services to provide wall-to-wall maps simplifying the complexity of the landscape surface through dedicated generalisation rules; a top-down approach. LUCAS is a statistical survey, which collects information on a sample basis, which is than extrapolated to represent the entire population. It is important to distinguish these two approaches. **LUCAS is providing statistical land cover and land use information based on a sampling grid**. **COPERNICUS (including CORINE) is providing land cover and land use coverage maps**. Copernicus is not intended to serve as a statistical base for land cover and land use estimation, for simple pixel counting is insufficient at the given scale to produce the required statistical accuracies (Gallego, 2006). Despite their different principles, which ensure independent information, **LUCAS and CLC can complement each other.** With the new High Resolution (HR) components there is space to further increase the contribution of LUCAS towards Copernicus land monitoring services. Modifications to the programs and their implementation could lead to an improved use by Copernicus land monitoring services (e.g. through adapted sampling approaches, nomenclatures). Also organisational measures could be employed to increase the understanding of what is observed through LUCAS but also to simplify the set of rules. Considering the LUCAS aims**, this study shall assess the usability of LUCAS for the various products in the land monitoring portfolio**, and provide recommendations for potential adaptations that would improve its usability, whilst not jeopardizing the key objectives and cost drivers of the LUCAS product itself.

2 The LUCAS Programme

LUCAS stands for ***l****and* ***u****se and land* ***c****over* ***a****rea frame statistical* ***s****urvey* and has been initiated by the Statistical Office of the European Commission (Eurostat) through first pilots in 2000. It is operationally run since 2009. The purpose of this survey is to collect statistical data on land cover/land use, agro-environmental and soil data across all European Union member states. It applies a harmonized in-situ field observation survey using a stratified area frame sampling based on geographically referenced observation points.

2.1 Objectives and legal framework

LUCAS is a specifically designed statistical survey and a comprehensive methodological concept as a **part of the European Statistical System** (ESS). Particularly, it contributes to a consolidated, systematic and organised statistical framework at European level. It provides **harmonised information to compile statistics for the EU** as a whole; of particular importance to Community policies and to address future transnational challenges. This context forms the legal basis of LUCAS and defines the legislative duties of Eurostat as laid down in Regulation No 223/2009/EC (OJ L 87/164, 31.3.2009), mandated through the Treaty establishing the European Community, and in particular Article 285(1) (97/C 340/01; OJ C 340, 10.11.1997, p. 173–306). Through the LUCAS program Eurostat fulfils its obligations for **European land resources monitoring**. LUCAS provides statistical information to the ESS in an applied, operational and pragmatic strategy in compliance with the European statistics code of practice[1] taking into account the fundamental principles of the UN on statistics[2].

Of important relevance for this study are the **additional objectives of LUCAS**, to contribute to the:

- Scientific progress in Europe (Regulation No 223/2009/EC point 26)
- Public access to environmental information (Regulation No 223/2009/EC point 28 & Directive 2003/4/EC)
- Application of the Aarhus convention (Regulation No 223/2009/EC point 28 & Regulation No 1367/2006/EC)

2.2 Project background & institutional setting

The LUCAS survey is part of the **Community Statistical Programme** (currently 2013-2017, Regulation No 1383/2013/EC)[3]. It forms a contribution of Eurostat to the ESS which integrates LUCAS into a collaborate network involving the relevant Member States authorities and National Statistics Institutions (NSI). It shall avoid duplication of work, reduce the burden for respondents and focus on cost efficiency, while ensuring impartiality, high quality and coherent treatment (Regulation No 223/2009/EC point 17,18,20) as well as scientific independence and reliability on the production of European statistics (97/C 340/01, Article 285 (2)).

LUCAS is an *in situ* survey, where surveyors collect data at about 275,000 individual observation points in the field distributed over all land cover types in all EU member states. LUCAS was

[1] http://ec.europa.eu/eurostat/web/quality/european-statistics-code-of-practice

[2] http://unstats.un.org/unsd/dnss/gp/fundprinciples.aspx

[3] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:354:0084:0084:EN:PDF

initially developed to provide early crop estimates for the European Commission and has **subsequently developed to a broader land cover/use survey** along the following timeline (see Figure 1):

- 2001 - 2003: The survey started with a pilot survey across all EU15 Member States, based on clusters consisting of 10 points with first attempts to observe landscape heterogeneity along transects.
- 2001 – 2007: Eurostat and JRC Ispra launched a number of studies to explore potential improvements, limitations and applications.
- 2006: The sampling methodology changed and shifted towards a broader land cover, land use and landscape survey scheme but without transect observations. The survey was executed as pilot in selected countries.
- 2007: With an extra focus on environmental information a pilot in a selected number of countries has been executed introducing soil parameter for the first time.
- 2009: LUCAS became an operational instrument of Eurostat. The survey was extended to cover 23 of the then EU-27 Member States (Bulgaria and Romania were covered in 2008; Cyprus & Malta were not covered). Top soil sampling was included in the survey for 10% of the sampled points. A three year repetition interval was introduced. The EEA Forest types were included.
- 2012: All EU-27 Member States were covered. Some changes to the nomenclature applied.
- 2015: The 2015 LUCAS survey is currently under production, with field surveyors across Europe collecting land cover/use data. All EU28 Member states are covered. Pilot project to include INSPIRE pure land cover classes.

The outputs from the LUCAS surveys are three types of information:

- Micro data: land cover, land use and environmental parameters associated to the single surveyed points,
- Point and landscape photos in the four cardinal directions,
- Statistical aggregates by land cover, land use at geographical level; these estimates are based on the point data conveniently weighted.

More information on LUCAS and access to the data can be found on the internet (Table 1).

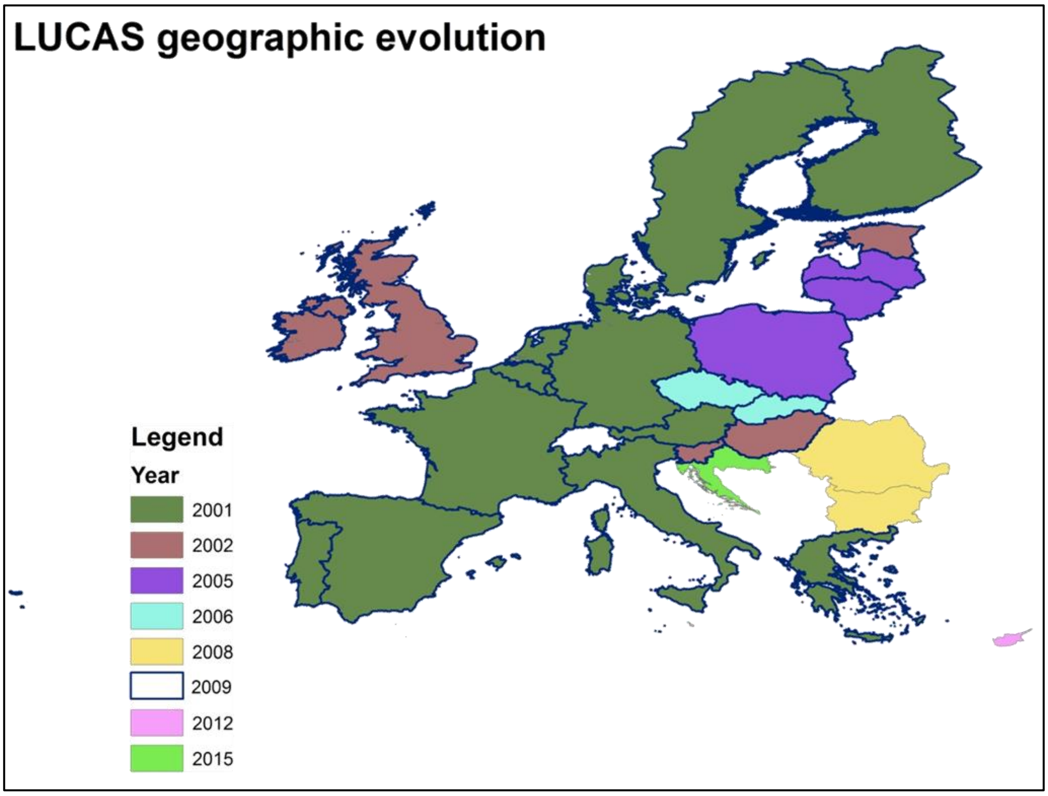


Figure 1: Geographic evolution of LUCAS. The map indicates in which year countries have been included in the LUCAS survey for the first time.

Table 1: Links to access to LUCAS data and information

Type of data	Source / link
LUCAS general information	http://ec.europa.eu/eurostat/statistics-explained/index.php/LUCAS_-_Land_use_and_land_cover_survey http://ec.europa.eu/eurostat/web/lucas/data/database
LUCAS methodology and technical instructions	http://ec.europa.eu/eurostat/web/lucas/methodology http://ec.europa.eu/eurostat/ramon/other_documents/lucas/index.htm
Eurostat LUCAS Web Viewer	http://ec.europa.eu/eurostat/statistical-atlas/gis/viewer/?myConfig=LUCAS-2009.xml
LUCAS micro data access	http://ec.europa.eu/eurostat/web/lucas/data/primary-data/2006 http://ec.europa.eu/eurostat/web/lucas/data/primary-data/2009 http://ec.europa.eu/eurostat/web/lucas/data/primary-data/2012
LUCAS meta data	http://ec.europa.eu/eurostat/cache/metadata/en/lan_esms.htm#contact1418758775745

The execution and extension of the past LUCAS pilots was based and financially covered through a number of individual decisions by the Council and the European Parliament (Decision 1145/2000/ EC of 22.05.2000, Decision 2066/2003/EC of 10.11.2003 and Decision 786/2004/EC of 21.04.2004), whereas the operational campaigns have been covered since January 2008 through Eurostat's budget with contributions from other DGs of the commission.

2.3 Project phases

In 2009, a **three year interval** was introduced to repeat the LUCAS surveys. Subsequently surveys were conducted in 2009 and 2012 while the 2015 survey is currently ongoing.
Usually a survey campaign is split into four dedicated phases:
(i) the preparation phase, which includes the contractual settings, kick off, dissemination of the actual field sample as well as revised methodological instructions and digital data processing infrastructure; in that phase all preparatory measures are being executed which are then (ii) installed and trained in order to mobilize the surveyors teams and quality control levels. The (iii) phase is the data collection and survey period, which is followed by a (iv) data cleaning, reviewing and reporting phase.
Before and after a particular LUCAS campaign the Commission has to process an individual set of steps (briefly simplified in Table 2).

Table 2: LUCAS project steps

Timing	LUCAS phase
t0-1year	Commission - Evaluation of tender
t0-1 – t0	LUCAS campaign - Contract, Kick-Off and preparation phase
t0	LUCAS campaign - Installation & training phase
t0	LUCAS campaign - Survey period
t0 – t0+1	LUCAS campaign - Reviewing & reporting phase
t0+1	Eurostat - Data processing & calculation of estimates
t0+1	Eurostat - Publication of estimates
ongoing	Eurostat - Process review, evaluation and user needs survey
t1-2	Commission - Methodological revision; evaluation and decision upon a new campaign
t1-1	Commission - Tender preparation
t1-1	Eurostat - Call for tender
t1-1	Commission – Evaluation of tender
t1-1 – t1	LUCAS campaign – Contract, Kick-Off and preparation phase
…	

2.4 Methods

2.4.1 The LUCAS sampling design

The LUCAS survey is an **area frame survey using points as sampling units**. Since the LUCAS 2006 campaign the statistical sample of the survey is selected using **two phase sampling with stratification** (Figure 2).

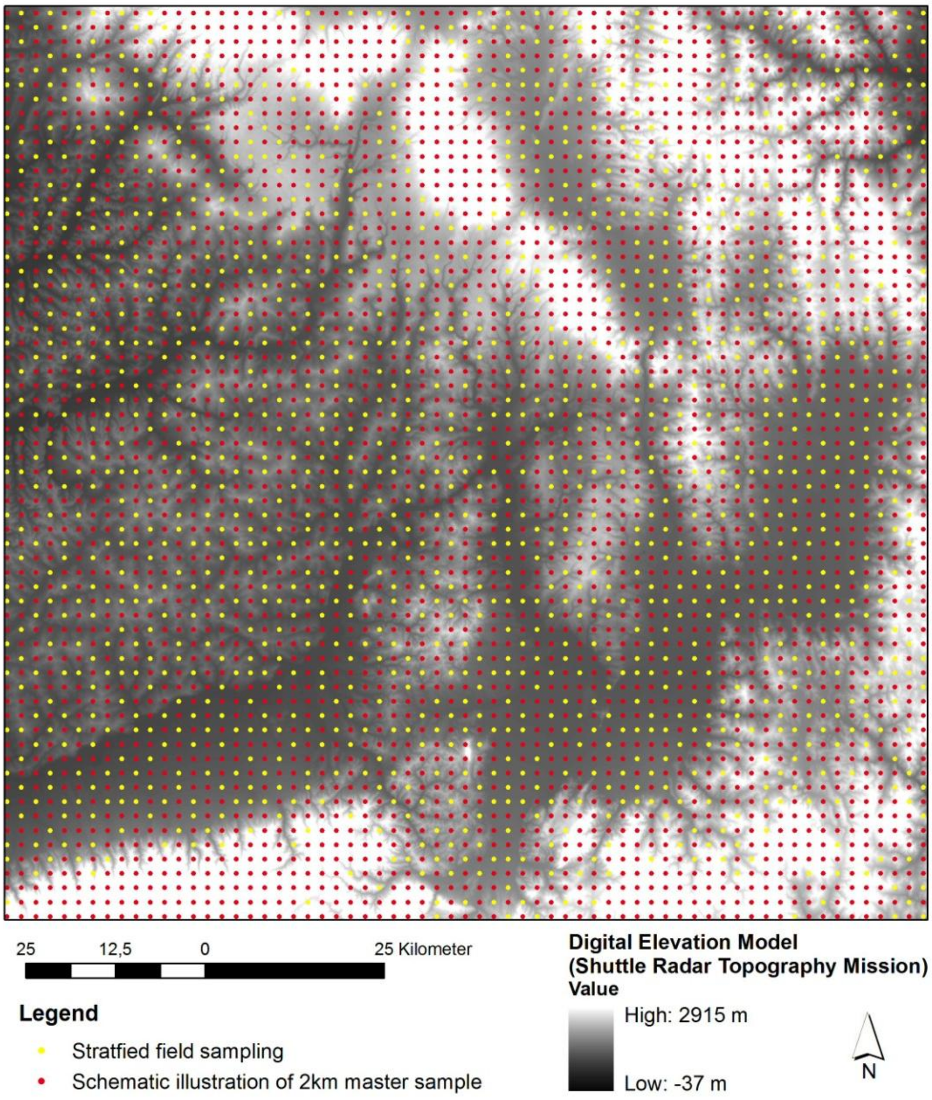


Figure 2: LUCAS two phase sampling design, yellow: stratifed field sample, red: schematic illustration of a 2 km grid as a master sample, background image: digital elevation model by Shuttle Radar Topography Mission © Nasa (figure extracted from Haub et al., 2013).

In the first phase a systematic and **regular 2 km grid of points** was overlaid on the whole EU territory. This grid of points is the master sample or frame where each point represents a proportion of the total population (area of the EU). **The LUCAS points are defined with a radius of 1.5 m** around the point as well as an extended observation window of 20 m radius for certain classes. Based on this grid design all sampling points have been allocated to one of seven major land cover classes by means of photo interpretation. That information is aimed to increase the efficiency of the final field sampling through thematic stratification, which in turn is the key to extrapolate the outcomes of the field observation back to the entire population (see Figure 3). **To stratify the master sample** all points of the master sampling frame were photo-interpreted and assigned to one of the following seven land cover classes:

- arable land
- permanent crops
- grassland
- wooded areas and shrub land
- bare land
- artificial land
- water

The interpretation of the master frame was done using mainly aerial images or best available satellite images with coarser resolutions (Gallego and Delincé 2010). For new member states in later campaigns the master frame was extended using the same method.

In the second phase **a subsample of points is selected from the stratified master sample to be visited in the field**. The selection of the points, number and allocation, is based on the assigned land cover class (defined weights per class) and specific target precision estimates. The allocation of the samples is further optimised using specific rules to improve the spatial distribution of the sample points and to minimize cases were samples fall close to each other and provide redundant information (see Gallego and Delincé 2010 and Jacques and Gallego 2006).

The selected subsample of points is then observed by surveyors and classified using the full LUCAS land cover / land use nomenclature. The survey takes place between March and September, earlier in the southern countries and later in the northern countries, thus providing data from the same vegetation season. The information collected from the field survey is used to generate statistics for the different land cover and land use parameters on different NUTS level and for the entire EU. The calculation of estimates, e.g. the surface of a specific crop, is straightforward using the known proportions of points classified as a specific crop within a stratum and the weight of the stratum (see Gallego and Delincé 2010 and Jacques and Gallego 2006). The proportions can be extrapolated to the entire population of the master sample or different NUTS level and transferred to absolute acreage.

An overview of the general survey design with the figures from the 2006 survey is given in the figure below.

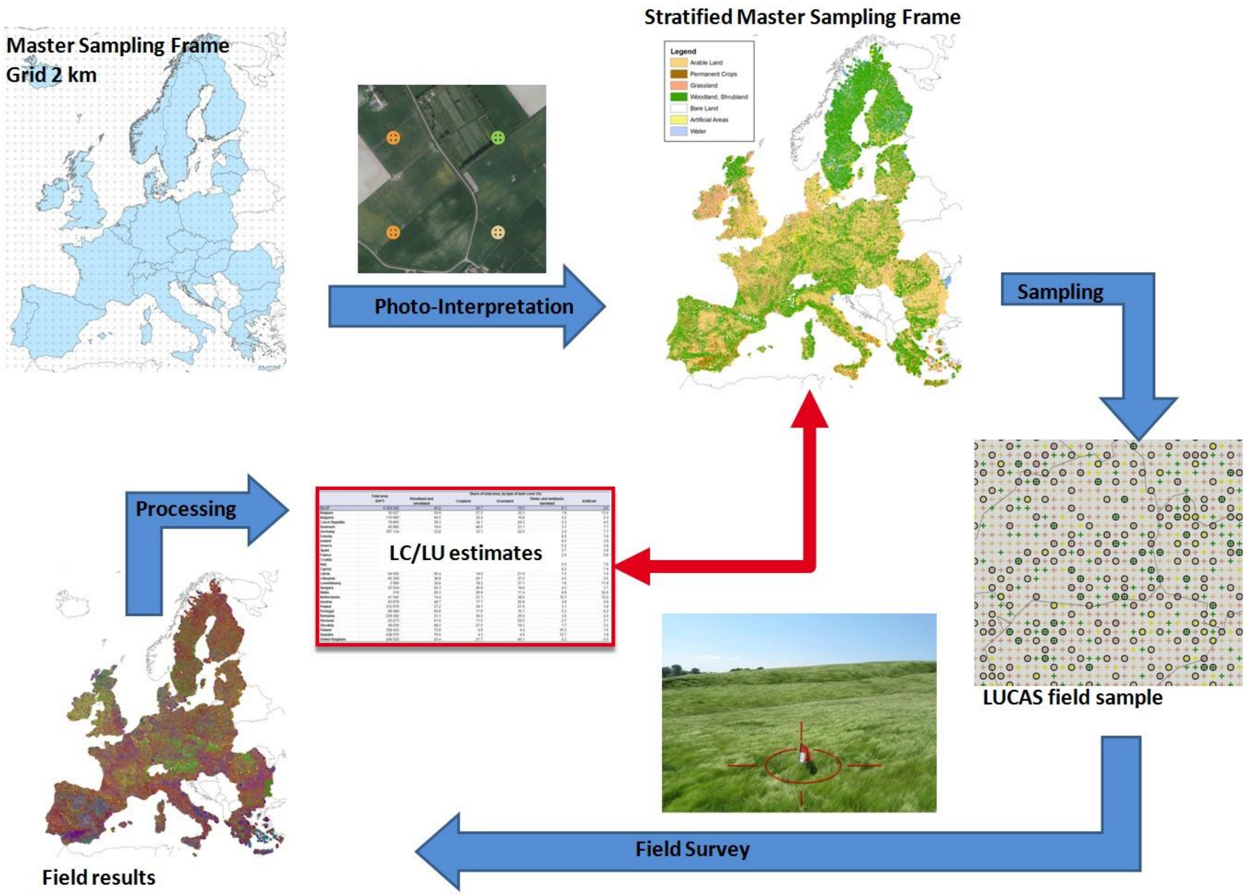


Figure 3: The LUCAS design (simplified from Jacques and Gallego 2006 p. 7)

Further specifications of the survey design are the **exclusion of points from the field survey which are considered too difficult or too expensive to access**.

- Points on small islands which are not connected by bridges to the mainland (for example the Balearic and Canary islands) are excluded using the NUTS units as geographical reference. Territories excluded from the different survey campaigns are provided at http://ec.europa.eu/eurostat/cache/metadata/en/lan_esms.htm.
- Points located above 1500 meters (1200 meters in 2006) have been excluded from the field sample. The altitude of the points is assessed using a Digital Terrain Model (DTM). Due to the coarse resolution of the DTM some points excluded might be below the threshold and vice versa (Gallego and Delincé 2010).
- In 2012 and 2015 the proximity to road network was also considered for the exclusion/selection of points.

Some sampling design changes have occurred since the pilot survey in 2006 due to a shift from an agricultural focus, in particular crop statistics, to a more broadly agro-environmental survey. For example, in the 2006 pilot survey the focus was merely on agriculture and the sampling rate 5 times higher for the agricultural classes than for the non-agricultural classes. In the following surveys, the sample rates have been adjusted to a more balanced selection. Requests for higher geographical precision lead to another sample design adaption in 2009, expressed in a shift to the sub-national level to draw samples independently from each NUTS level 2 region (Martino et al. 2009). **Transects are again a fix part of the survey since 2009** (after initial tests in 2001 and 2003) to measure the diversity of the landscape and other environmental parameters.

2.4.2 Technical implementation of the survey

Since the operational status and particularly since the campaign in 2012 LUCAS is covering all EU member states, which is representing an area of more than 4.3 Mio km². This is a result of 13 years of close inter-institutional collaboration between Eurostat, the EC Directorates General (DG) for Agriculture, the DG for Environment, the EC Joint Research Centre (JRC), the European Environment Agency (EEA), the National Statistics Authorities of the member states, and numerous research institutions as well as private companies. According to the EUROPEAN COMMISSION EUROSTAT (2010) they achieved all together (Haub et al., 2013):

- A high level of harmonization and standardization of the data collection
- A consolidated standard questionnaire and nomenclature for the data collection
- A very high completeness of data and metadata
- A powerful tool for the validation at the level of data providers
- Transparent documentation of the data validation system, including
  - Different actors/levels of control
  - Various training steps
  - Continued monitoring of the work
  - Independent data quality checks
  - Full traceability of corrections and enhancement procedures
- A combination with a good ability to react quickly and flexibly to specific user demands for tailor-made data extractions.

Generally LUCAS contains three major sets of parameters, which are consisting of (a) the point survey, (b) the transect observations and (c) the soil component. The following chapters are briefly introducing the key criteria of these survey parameters, whereas for full details reference is made to the methodological documentation (Links see Table 1).

2.4.2.1 Point survey

The main information is collected at the LUCAS point which distinguishes between **land cover and land use** as separate information recorded. **Land cover is the physical cover of the re-**

lated landscape in a diameter of 3 or 20 m around the point coordinate (Figure 4**)**, and **land use is the related socio-economic land use**.

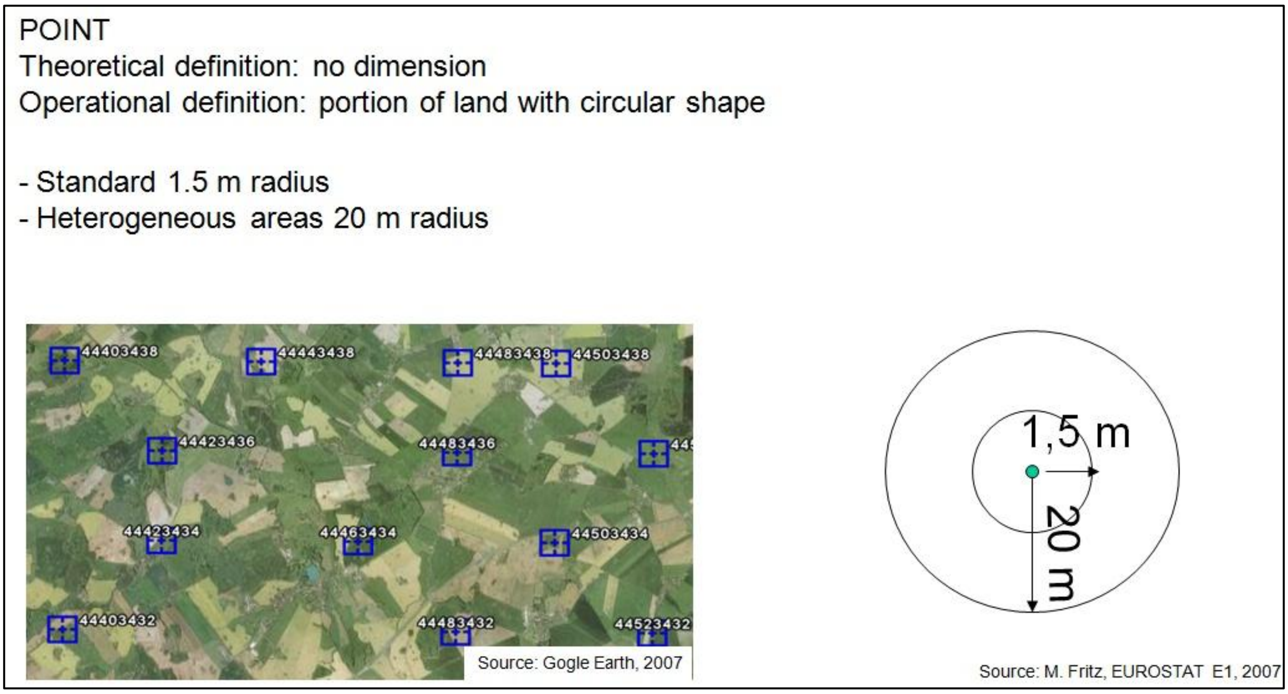


Figure 4: Schematic illustration of LUCAS sampling unit (Eurostat, 2007 & Google Earth, 2007).

It is important to note, that only through **the combined LUCAS LC/LU code**, a full conclusion can be drawn about the specific sampling point location.

The following example should illustrate this: imagine a (i) permanent agricultural grassland versus (ii) a football ground. Both sampling points have a LC1 code = E20 for grass land, but in combination with the LU code U111 (=agriculture) or U362 (=sport) the sport field can be separated from the farmland. In addition more than one LC/LU code can be applied at the point, for example to identify a sport field with agricultural use (Figure 5)

Figure 5: Example of applying more than one LU code in LUCAS (left: E20=grassland, U111=agricultural use / U362 = recreational use, additional information = not grazed; right: E20, U111)

In addition to LC / LU information numerous more detailed parameters (see chapter 2.5) are collected at the LUCAS point including geo-referenced landscape pictures to the four cardinal directions (see Figure 6).

Figure 6: Schematic illustration of LUCAS point and cardinal directions of landscape photos in Bulgaria. Landscape photo © European Union, source: LUCAS 2012 (figure extracted from Haub et al., 2013).

2.4.2.2 Transect observation

The second major information is the collection of **transect information about land cover and linear features** along a line extending 250m eastwards of each LUCAS point (see Figure 7). Through this information it is possible to generate indicators on landscape diversity and heterogeneity including the following parameters (Palmieri et al., 2011):

- Landscape richness
- Landscape structure
- Landscape dissection
- Landscape Shannon diversity Index
- Landscape Shannon evenness Index

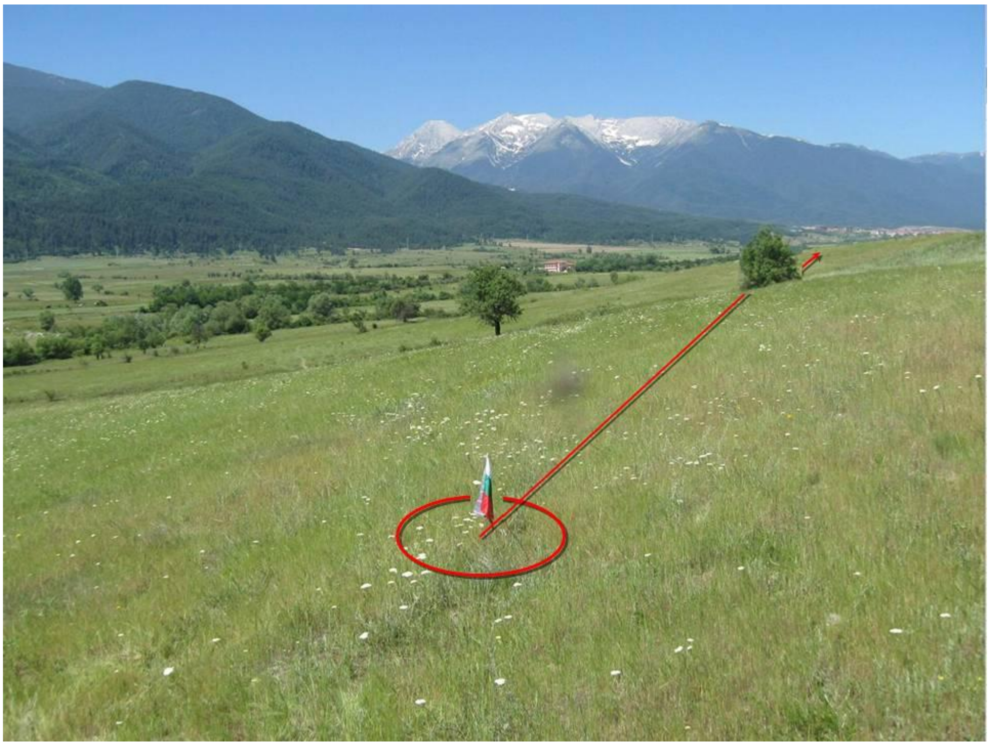


Figure 7: Schematic illustration of LUCAS point and transect in Bulgaria. Landscape photo © European Union, source: LUCAS 2012 (figure extracted from Haub et al., 2013).

2.4.2.3 Soil component

Soil samples have been collected for the first time in 2009 and were again collected in 2012 and the current 2015 campaign at about 10% of the visited points. The analysis of the soil samples from the LUCAS 2009 data collection exercise provided publicly available information on (Tóth et al. 2013)[4]:

- soil types,
- soil textures,
- pH levels,
- organic carbon,
- phosphorous, nitrogen and extractable potassium,
- soil erosion,
- susceptibility to compaction.

Figure 8: LUCAS soil component, training in a forest source: EFTAS, 2009

2.5 Data model and nomenclature used

As introduced in the above chapter **LUCAS contains three major components**, which are observed in the field. In addition to (a) the point survey, (b) the transect observation and (c) the soil component, **each point contains a comprehensive set of metadata**, which are aimed to document the detailed conditions, time and date during the observations. Understanding these parame-

[4] The soil data is available after filling out a registration form at: http://eusoils.jrc.ec.europa.eu/projects/Lucas/Data.html

ters is important to use and apply the LUCAS data. They are a substantial part of the data model in addition to the landscape photos and the collected soil sample (see Figure 9). Although there was some variations and evolution over time, **the key information model is a stable factor since 2009** as shown in the following figures (see also Annex 2 for field forms from 2009 and 2012).

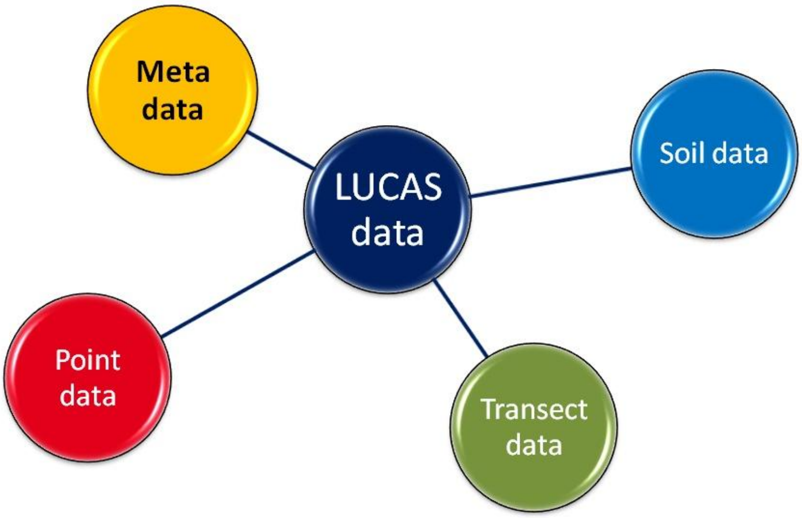


Figure 9: LUCAS data model.

A first (meta) data block describes the circumstances of the observation with header parameters. Such information contain date, time, position of observation, distance to the point, potential impediments to reach the point, type of observation, and possible remarks related to each point. The main data block at point level contains LC, LU, percentage of coverage, height of objects, and other class related parameter such as e.g. water management for crop land, as well as the landscape photos related to the point. Soil parameter and transect information are completing the current set of observations.

Metadata

Identification

A	**Surveyor ID**:	B	**Point ID**:

Access to point

1	**Date:**	7	**Type of observation:** 1 ☐ Field survey, point visible, 0-100m to pt 2 ☐ Field survey, point visible, >100 m to pt 3 ☐ Photo-interpretation, point not visible 4 ☐ Point not observed. PI not possible 5 ☐ Marine sea 6 ☐ Out of national territory	12	**Elevation** (meters)**:** **(N.R. = 8888)**
2	**Start time: (HH:MM)**				
3	**End time: (HH:MM)**	8	**GPS coordinate system:** 1 ☐ WGS84 2 ☐ Problem with signal 8 ☐ N.R.	13	**Precision** (meters)**:** (N.R. = 8888)
4	**Car park Latitude:** (N.R. = 88,888888)	9	**Point Latitude:** (N.R. = 88,888888)	14	**Distance to the point:** (N.R. = 8888)
5	**Car park Longitude E/W:** ☐ E ☐ W ☐ 8	10	**Point Longitude E/W:** ☐ E ☐ W ☐ 8		
6	**Car park Longitude:** (N.R. = 88,888888)	11	**Point Longitude:** (N.R. = 88,888888)		

Comments

C	**Description of the way to the point (previous campaign)**
15	**Description of the way to the point [structured comments / other]**

Point observation

16	**Remarks about point observation [structured comments / other]** *(why observation not at the point, ground document not clear, etc.)*

Point data

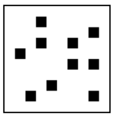
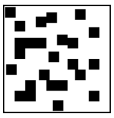
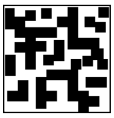
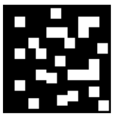
Land cover and land use

17	**Direction:** 1 ☐ on the point 2 ☐ north 3 ☐ east 8 ☐ N.R.	18	**Radius:** 1 ☐ 1.5 m 2 ☐ 20 m 8 ☐ N.R.	19	**Plot area (in ha):** 1 ☐ area < 0.5 2 ☐ 0.5 ≤ area < 1 3 ☐ 1 ≤ area < 10 4 ☐ area ≥ 10 8 ☐ N.R.		
20	**LC1:**	23	**LC2:**	29	**LU1:**	32	**LU2:**
21	**LC1 plant species:**	24	**LC2 plant species:**	30	**LU1 land use type:**	33	**LU2 land use type:**
22	**Percentage of land coverage (%) LC1:** 1 ☐ %LC1 < 5 2 ☐ 5 ≤ %LC1 < 10 3 ☐ 10 ≤ %LC1 < 25 4 ☐ 25 ≤ %LC1 < 50 5 ☐ 50 ≤ %LC1 < 75 6 ☐ 75 ≤ %LC1 < 90 7 ☐ %LC1 ≥ 90 8 ☐ N.R.	25	**Percentage of land coverage (%) LC2:** 1 ☐ %LC2 < 5 2 ☐ 5 ≤ %LC2 < 10 3 ☐ 10 ≤ %LC2 < 25 4 ☐ 25 ≤ %LC2 < 50 5 ☐ 50 ≤ %LC2 < 75 6 ☐ 75 ≤ %LC2 < 90 7 ☐ %LC2 ≥ 90 8 ☐ N.R.	31	**Percentage of land use (%) LU1:** 1 ☐ %LU1 < 5 2 ☐ 5 ≤ %LU1 < 10 3 ☐ 10 ≤ %LU1 < 25 4 ☐ 25 ≤ %LU1 < 50 5 ☐ 50 ≤ %LU1 < 75 6 ☐ 75 ≤ %LU1 < 90 7 ☐ %LU1 ≥ 90 8 ☐ N.R.	34	**Percentage of land use (%) LU2:** 1 ☐ %LU2 < 5 2 ☐ 5 ≤ %LU2 < 10 3 ☐ 10 ≤ %LU2 < 25 4 ☐ 25 ≤ %LU2 < 50 5 ☐ 50 ≤ %LU2 < 75 6 ☐ 75 ≤ %LU2 < 90 7 ☐ %LU2 ≥ 90 8 ☐ N.R.

If LC CXX, or D10 or E10 & area size ≥ 0.5 ha	**If height of trees at maturity above 5 m**

26	**Height of trees at the moment of survey** 1 ☐ < 5 m 2 ☐ ≥ 5 m 8 ☐ N.R.	27	**Height of trees at maturity** 1 ☐ < 5 m 2 ☐ ≥ 5 m 8 ☐ N.R.	28	**Width of feature:** 1 ☐ < 20 m 2 ☐ ≥ 20 m 8 ☐ N.R.	

35	**Land management:** 1☐ Visible signs of grazing 2☐ No signs of grazing 8☐ N.R.	36	**Special status:** 1 ☐ Protected 2 ☐ Hunting 3 ☐ Protected and Hunting 4 ☐ No special status 8 N.R.	37	**Special remark on land cover/use:** 1 ☐ Tilled and/or sowed 2 ☐ Harvested field 3 ☐ Clear cut 4 ☐ Burnt area 5 ☐ Fire break 6 ☐ Nursery 7 ☐ No Remark 8 ☐ N.R. 9 ☐ Temporarily dry (river bed / lake) 10 ☐ Temporarily flooded


10%

25%

50%

75%

90%

INSPIRE Pure Land Cover Classes*

	Class	**Percentage (5% steps); Total = 100%**
38	Coniferous forest trees	
39	Broadleaved forest trees	
40	Shrubs	
41	Herbaceous plants	
42	Lichens and mosses	
43	Consolidated (bare) surface	
44	Unconsolidated (bare) surface	
45	Other	

* Only for points with LC1=CXX, DXX, EXX or FXX

Water management*

46	**Presence of water management:** *(Only if LU = U111 or U112)* 1 ☐ Irrigation 2 ☐ Potential irrigation 3 ☐ Drainage 4 ☐ Irrigation and drainage 5 ☐ No visible water management 8 ☐ N.R.	48	**Source of irrigation:** 1 ☐ Well 2 ☐ Pond/Lake/Reservoir 3 ☐ Stream/Canal/Ditch 4 ☐ Lagoon/Wastewater 5 ☐ Other/not identifiable 8 N.R
47	**Type of irrigation:** 1 ☐ Gravity 2 ☐ Pressure: Sprinkler irrigation 3 ☐ Pressure: Micro-irrigation 4 ☐ Gravity/Pressure 5 ☐ Other/not identifiable 8 N.R.	49	**Delivery System:** 1 ☐ Canal 2 ☐ Ditch 3 ☐ Pipeline 5 ☐ Other/not identifiable 8 N.R.

* Assessed on the whole parcel

Photos

	Type	**Taken**	**Not taken**	**Not rele-vant**	**Photo ID**	**To be anonymised**
58	Point	1 ☐	2 ☐	8 ☐		☐
59	Crop – Cover	1 ☐	2 ☐	8 ☐		☐
60	North	1 ☐	2 ☐	8 ☐		☐
61	East	1 ☐	2 ☐	8 ☐		☐
62	South	1 ☐	2 ☐	8 ☐		☐
63	West	1 ☐	2 ☐	8 ☐		☐
64	Irrigation	1 ☐	2 ☐	8 ☐		☐
65	Transect	1 ☐	2 ☐	8 ☐		☐
66	Soil	1 ☐	2 ☐	8 ☐		☐

Do not forget to take the soil, irrigation and transect end pictures!

Additional photo(s)

67	Type	Photo ID	To be anonymised
			☐
			☐
			☐
			☐
			☐

68	Remarks about the photos [structured comments / other]

Transect data

Transect

E	Transect (previous campaign)

56	Transect	01	02	03	04	05	06	07	08	09	10	11	12
	O → → : LC codes												
	Transect	13	14	15	16	17	19	19	20	21	22	23	24
	O → → : LC codes												
	Transect	25	26	27	28	29	30	31	32	33	34	35	36
	O → → : LC codes												

57	**Remarks about the transect [structured comments / other]** *(e.g. reasons for premature end of transect interpretation, PI)*

Soil data

Soil lucas-soil@jrc.ec.europa.eu

D	**Is this a soil point?** 1 ☐ Yes 2 ☐ No	50	**Is the soil sample taken?** 1 ☐ Yes 2 ☐ Not possible 3 ☐ No, already taken 4 ☐ No sample required 8 N.R.	51	**Soil label (if sample taken)** (N.R. = 88888) ☐☐☐☐☐
52	**Can you see any sign of ploughing in the plot?** 1 ☐ Yes 2 ☐ No 8 N.R.	53	**Percentage of residual vegetation on the surface:** 1 ☐ %RC < 10 2 ☐ 10 ≤ %RC < 25 3 ☐ 25 ≤ %RC < 50 4 ☐ %RC ≥ 50 8 N.R.	54	**Percentage of stones on the surface:** 1 ☐ %S<10 2 ☐ 10 ≤ %S < 25 3 ☐ 25 ≤ %S < 50 4 ☐ %S ≥ 50 8 N.R.

55	**Remarks about the soil sample [structured comments / other]**

2.5.1 LUCAS metadata

The metadata which are captured for each LUCAS point are a **precondition to understand and correctly apply the observation information**. Besides the time and date of the observation, the position of the surveyor and the distance to the LUCAS point are described here. It is important to note, that LUCAS points cannot always be reached close by. In those cases, the distance and direction towards the point are mandatory metadata to understand the content of the landscape photos. Another standard parameter is the type of observation, which generally explains if an observation was feasible or if any major impediment limited the access to the related point.

These parameters are crucial for further GIS processing, given that **LUCAS data are mostly geo-located through the coordinates of the original LUCAS points rather than the actual position of observation**.

2.5.2 LUCAS point information

The heart of the LUCAS information are the point information itself, consisting of separate parameters for **land cover (LC) and land use (LU)** together with the **systematic landscape and point photos**. In addition to this an extra focus is drawn here to the applied observation radius (standard radius or extended radius) and if the point falls on a linear feature or a boundary between different land cover types. Additionally **percentage of the related land cover, height of the particular features and the size of the related plot are recorded here**. Depending on the observed LC **further in depth information are recorded**, such as the presence and type of agricultural irrigation, forest types or special woodland states. In 2015, INSPIRE Pure Land Cover Classes have been added to that section.

2.5.3 LUCAS transect information

The transect information is an **alpha numeric sequence of codes of significant landscape features** and land cover changes starting at the LUCAS point **along a straight line of 250m towards East**. It serves to compute different landscape indicators such as landscape richness, structure, dissection, or the Shannon diversity and evenness indices (Palmieri et al., 2011).

2.5.4 LUCAS soil data

The main result of the soil component at the level of the LUCAS field activities is a **500g soil sample taken as a mixed sample from 5 sub plots that are allocated around a LUCAS point**.
These soil samples are collected in all countries as a 10% subsample of the LUCAS field sample.
Along the soil collection a number of survey circumstances are documented in a close relation to the overall LUCAS meta data, as well as information upon residual vegetation, percentage of stones as well as visible signs of ploughing.
Further analysis are being investigated for the parameters texture, organic matter content, pH, and heavy metals, in order to assess the state of the soil across Europe (EUROPEAN COMMISSION JRC 2012).

3 Background knowledge on the use of LUCAS

3.1 Links to national statistical programs

3.1.1 Top down approach: The use of LUCAS in national statistical and mapping programs

LUCAS in general was designed to support the European Commission with comparable statistical data that are captured in a harmonized way for the pan-European. The density of the point grid (2 x 2 km), upon which the visited points are selected, is high enough to apply it for the estimation of LC/LU statistics at the European level. To calculate reliable and robust statistics at the national or even regional level (down to NUTS3), the density of the point grid would have to be at least four times higher, i.e. based on a 1 x 1 km grid. Therefore, at least in the case of Germany, LUCAS data have neither been used for official statistical purpose nor for any decision making process on national level.

LUCAS point data was used in a limited extent as ground truth information for the Digital Land Cover Model DLM-DE (a German national mapping activity produced by the Federal Agency for Cartography and Geodesy - BKG). In some cases, the point data in combination with the ground photos were useful for manual comparison checks. However, due to some technical constraints of the LUCAS point data the automated usability of such data was limited. For Example, sometimes the point´s visited location on the ground (different from the theoretical coordinates according to the 2x2 km reference grid) appeared uncertain, which lead to unclear LC information content connected to the cross-checked vector polygon data to be validated. Also, the representativeness of a point located inside a large LC/LU polygon is limited; a typical case for a small scale national topographic or land cover vector dataset like the German ATKIS Basis-DLM or DLM-DE. This leads to constraints in the automated data extraction from LUCAS point data and its integration to national topographic data.

Furthermore, Eurostat results of LC/LU area size estimation for Member States based on LUCAS data are not coherent if compared to the Member States´ own national statistical data on LC/LU and show a degree of discrepancy that is dependent on the land cover categories with variations from country to country. It is fair to note that a) LUCAS is not intended to provide national statistics and b) that even different sources within the same country often give different results, due to different input data, sampling designs, extrapolation methods etc.

3.1.2 Bottom-up approach: Using national statistics to contribute to LUCAS (LUCAS Grant Pilot Studies)

In 2012, Eurostat has launched a pilot study in the form of a grant (No. 40301.2012.002-2012) addressing the overall question how European Member States can contribute to the pan-European statistical dataset of LUCAS through national data sources. The study is entitled “Pilot studies on the provision of harmonized land use/land cover statistics - Synergies between LUCAS and the national systems (LUCAS Grant)”.

The responsible unit at Eurostat was the Directorate E “Sectoral and regional statistics”, Unit E-4 “Regional statistics and Geographical Information”.

- Purpose of the grant

The project aimed at contributing to the harmonisation of land cover/use statistics and data collection methods between Eurostat and the Member States. It was separated into Part A and B. Part A consisted of the delivery of harmonised and quality-assured land cover/use statistics (tables) according to the LUCAS nomenclature and a given precision. Part B of the grant consisted of the delivery of a feasibility study and a concrete plan on how to integrate already operational national in-situ surveys with the LUCAS requirements; in detail how to extract data from national sources to attach them to LUCAS point locations.

Most participating countries decided to just apply for Part A (delivery of statistical tables), the Netherlands suggested a way how to populate the LUCAS points (Part B).

- Time frame and participating countries

The time interval of the first phase of the grant was between 2012 and 2014. The participating countries were Portugal, Italy, Greece, Netherlands, Poland, Norway and Germany. It was extended from 2014 onwards to the countries Austria, Finland, Rumania, France and Hungary and conducted again in Italy with different aspects compared to the first phase in 2012-2014.

- Connection between Copernicus / remote sensing data and LUCAS grant

The content of the following paragraphs for the countries (in alphabetical order) has been extracted from the national reports in the frame of the LUCAS grant study 2012-2014. It is not an official summary but rather an impression on the use of LUCAS in national statistics, without being exhaustive.

DE: In the case of Germany, no Copernicus data have been used in national or regional LC/LU statistics. The official land use statistics are traditionally compiled based on the cadastral data from the Länder and Municipalities. This means that it is not a survey executed by the statistical office itself, but relies on third-party datasets, of which the maintenance and updating lies in the responsibility of the cadastral authorities. Since April 2015, a cooperative project has been launched by the Federal Statistical Office (Destatis) with the Federal Agency for Cartography and Geodesy (BKG) under the framework of a national Copernicus fund. The projects target is to assess the potential of Copernicus products (satellite imagery like Sentinel-2 and derived products like HRL) to support the compilation of land cover and land use statistics, in the sense of fulfilling national as well as European requirements on LC/LU statistics (from Eurostat). This will include also the assessment of the Digital Land Cover Model for Germany (DLM-DE), which is produced by integrating topographic vector data with remote sensing data by interpretation and automated analysis of satellite imagery.

EL: planned to integrate their national data sources with other kinds of information including satellite imagery. Orthophotos are used for land surveying activities and LPIS mapping. Indirectly, remote sensing information was used through the connection with CORINE LC data.

IT: In Italy official, consistent, complete and replicable statistics on LC/LU are not available at the moment, but the supply of public or non-public geographical data is large, though strongly fragmented. The reason for this fragmentation is that in Italy there is a plurality of public entities that meet specific objectives, although different from each other.
IT has included the Copernicus products CLC, Urban Atlas and HRLs as potential LC/LU sources of information. As the national situation consists of a patchwork of various data sources on LC or LU, all possible sources have been integrated and compared with the mapping results of LUCAS sample point to create a kind of plausibility indicator.

NL: The Dutch approach for the grant included the LGN7 data set (Dutch land cover database) as a source of information to derive LUCAS-conform statistical data. As the LGN is partly based on remote sensing data (besides topographic data, aerial photographs, previous LGN versions and Dutch natural areas database), satellite imagery was theoretically involved in the estimation of LC/LU statistics. However, Copernicus data have not yet been used to contribute to LUCAS via national LC/LU statistics.

NO: The Norwegian colleagues used AR-STAT among others as a source of information for national LC/LU statistics. AR-STAT is compiled by NFLI every 3rd year for statistical purposes. It is a complete land resource data set comprising the whole of mainland Norway. It is composed of data from three sources: AR5 as a national land resource map at a scale of 1:5000, topographic maps at a scale of 1:50 000 and AR-Mountain (a satellite based map). The main data source for AR-STAT is AR5. Areas in AR5 where the information is inadequate are supplemented with data from the topographic map. Finally, areas left in AR5 and the topographic map as “open land” with no further information are completed with data from AR-Mountain. When analysing the satellite imagery for AR-Mountain data they are expected to exhibit some degree of homogeneity in terms of land cover. The aim is therefore not to map a priori defined vegetation classes, but rather to make a map of classified spectral values and to describe and understand subsequently these classes in terms of land cover content. The result is a partition of the entire country, where each location is represented with the best available land resource information.

In this way satellite data has been used to estimate LC/LU statistics only for those sparsely populated areas dominated by natural and semi-natural landscape, which are not mapped in other more precise and ground-truthed campaigns. The statistical information on grassland, shrub, and bare land (in terms of the LUCAS class definitions) for these areas are less reliable, because they are not backed by ground truth in-situ data. This applies also in parts to remote forested and wetland areas that are interpreted from satellite imagery.

Built-up area statistics is based only on national land use maps (topographic, cadastral). No remote sensing data are used so far to differentiate between the land use of parcels and the land cover within the parcels (not only buildings and sealed areas but also associated land), but it was considered to use Sentinel-2 data to explore the differentiation in future.

PL: In Poland, no Copernicus products are so far involved in the production of national LC/LU data. The Space Research Centre of the Polish Academy of Sciences is only involved in research activities; no operational work is currently being carried out related to the feeding and maintenance of land cover and use databases. The research work is performed mainly within EU projects. Due to the nature of these projects and the location of the surveyed areas, they cannot be regarded as a permanent source of supplementary information serving the purposes of the LUCAS programme.

National vegetation maps have been created through analysis of MODIS data, but the spatial resolution of it is very coarse and not high enough for LC statistical purposes.

For high resolution data capture also the use of drones is discussed in the polish report. It can help to capture data on ground situations very quickly, but at a geographically limited extend and also only feasible on a limited number of locations.

Statistical figures about forest areas are in general a politically sensitive issue. In the case of Poland is seems particularly difficult to obtain reliable and up-to-date information on forest / wooded areas from official sources. The future data of Sentinel-2 might be able to contribute for a solution to this topic.

PT: In the Portuguese report, satellite imagery from the Copernicus contributing missions RapidEye, SPOT and ResourceSat are mentioned as available data sources.

The object based image analysis (OBIA) of satellite images revealed potential for the segmentation of the geometries of existing geographical data into more detailed LC LUCAS classes, but also to estimate area sizes for point based geographic information related with LU LUCAS classes. However, it became clear that the results of these exercises would benefit from higher resolution images, which in turn pose the challenge of dealing with an enormous amount of information and the respective capacity for data processing.

Due to the lack of appropriate land use data, remote sensing assessment was also used to extract LU categories which are associated to homogeneous LU at the object level. However, the Portuguese results showed that satellite data with medium spatial resolution (6.5 m) has some limitations regarding the identification of land use. Obtaining better distinction of urban land cover classes with similar coloration requires very high resolution imagery.

In conclusion, it can be said, that many Member States have either access to remote sensing data or derived products through Copernicus programme, or have already tested these data to some extend for statistical purposes. However, none of the countries has already in place a fully installed and operational procedure that relies on Copernicus data as a constant source of information for LC/LU statistics. The advantages and short comings of remote sensing methods are reflected, and plans are made for a stronger integration of such data for future data collection phases.

An important issue is to effectively combine the technical advantages of both the in-situ survey LUCAS and the remote sensing methods. In particular, information that is rather difficult to extract from satellite imagery must be collected during a field survey, like for example land management practices, cultivation measures, status, plant communities etc..

3.2 Recent surveys on the use of LUCAS in Copernicus land monitoring services

3.2.1 EEA Survey 2014

In 2014, the EEA has carried out a survey on the use of LUCAS data in the production of CLC 2012 and COPERNICUS high resolution layers among NRCs for land cover, NFPs and service providers of HRLs ("LUCAS 2018 & beyond - review of use of LUCAS data in the production of land cover products").

The results showed that **LUCAS was used to some extent in the CLC production** (Figure 10) **and HRL production/validation and enhancement/verification** steps (Figure 11). Both LC/LU and LUCAS photos were used, while other environmental parameters were not used. Asked for potential **improvements** to the LUCAS survey respondents mentioned that LUCAS should be **stronger harmonized with (national) LC/LU inventories and more closely integrates into the Copernicus process**. The need to **increase the density of survey points** was mentioned, e.g. for less frequent class.

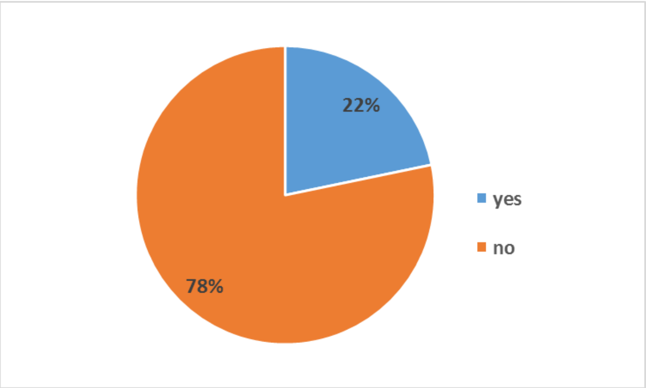


Figure 10: Use of LUCAS in CLC 2012 production (Source internal EEA survey 2014)

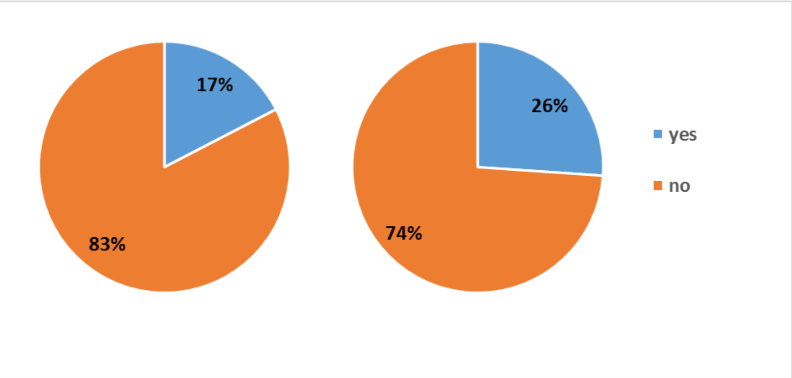


Figure 11: Use of LUCAS in HRL 2012 production/validation (left) and enhancement/verification (right) (Source internal EEA survey 2014)

3.2.2 Online survey

In the course of this study additional questions on the use of LUCAS as well as its weaknesses and strengths were addressed to the EEA survey addresses (namely the NRCs) as well as additional experts in the field of CLC and Copernicus listed by Eurostat. The survey addressed 74 experts and was conducted as an online survey. Despite the short timeframe (during summer holidays, July – August 2015) 20 answers were received and analysed. The detailed responses can be found in Annex 1.

Half of the respondents (i.e. no = 10) have used LUCAS data before. Reasons for not using LUCAS previously by the remaining respondents were manifold. It appeared that there is **to some extent a lack of information** about LUCAS, and that the **data access was seen as inadequate**. Specific reasons for not using LUCAS data included also the **availability of better data at national and regional scales**.

Asked about the LUCAS data use, **all three components have been mentioned** (LC/LU micro data, photos and statistics), mostly for **verification and validation tasks**. Other tasks included stratification as well as the use of LUCAS as ancillary data in the production of LC/LU maps. Some of these applications are well documented (e.g. the use of LUCAS for an accuracy assessment of CLC 2006[5]), others are currently under testing or development (e.g. the application of LUCAS data for national questions, see chapter 3.1).

The **strength of LUCAS** is mostly seen in the **harmonized and complete approach across Europe at regular intervals**. This systematic approach provides reliable estimates and a unique combination of ground surveyed LC/LU information and photos.

Limitations of LUCAS have been mentioned regarding the **mismatch of LUCAS and Copernicus data** definitions, the pure **focus on point and transect** (missing for example complete PSU coverage), **missing additional (non-agricultural) information** (forest and semi-natural areas) and the too **complicated (stratified) sampling design** and the presence of “fake” LC/LU changes, i.e. changes due to methodological changes.

---

[5] http://www.eea.europa.eu/publications/technical_report_2006_7

Changes to the LUCAS sampling design and the LC/LU classes were mostly mentioned to improve the use of LUCAS (e.g. to better address forest and semi-natural areas and improve the representativeness of some class transitions). Possible modifications could be **to increase the number of sampling points** for underrepresented classes/class transitions**,** improve the **variable quality of the photographic documentation**, further **harmonize and extend LC/LU classes** with respect to the CLC/ Copernicus nomenclature and include **wall-to-wall sampling of area around** LC/LU (national proposal by NOR). Furthermore, LUCAS should be **geographically extended** to include EEA cooperating countries and EFTA countries.

Asked about the **underlying mandates** or thematic domains addressed by the **Copernicus land monitoring** services, the answers were not very conclusive. Monitoring and documenting change in land characteristics across Europe has been named as the broad impetus for Copernicus, with reference to the Water Framework directive as well as the Birds and Habitat directive.

Modifications to the Copernicus sampling design and nomenclature were again the most mentioned aspects to improve the uptake of LUCAS data. Through a closer **synchronisation of the project phases** and a harmonisation of the data models both programmes could benefit through for example a combined use, standardized Copernicus validation procedures (using LUCAS input) or monitoring of LUCAS between surveys. This might enable better data quality estimates and lead to an improved acceptance of Copernicus products.

In summary the following recommendations can be derived from this (non-exhaustive) survey and were taken into account in the subsequent in-depth analysis, if applicable:

- General recommendations (out of the scope of this study)
    - Improve data access
    - Improve information (transparency) of data model/content
    - Provide simplified and convenient documentation
    - include wall-to-wall sampling
    - streamline quality of photographic documentation
- Recommendations related to Copernicus needs
    - Extend LUCAS LC/LC codes
    - Adapt sampling design
    - increase sample for less frequent classes and non-agricultural classes (forest, semi-natural)
    - harmonize project phases
    - Adapt/Link LUCAS and CLC/Copernicus nomenclatures (maybe via EAGLE model)

4 Copernicus land monitoring components

4.1 CORINE Land Cover

4.1.1 Project background & institutional setting

The CORINE Land Cover (CLC) initiative has a longstanding tradition of providing land cover and land use information over Europe at regular time intervals. It is the largest European land monitoring project, having a long heritage, a well-documented nomenclature (Bossard et. al 2000), clear implementation guidelines (Büttner et. al 2007) and a well-established user community. CLC is the primary land cover / land use (LC/LU) dataset for the EEA and is used in reporting, indicator development and environmental assessment. Since its launch in 1986 it has become one of the flagships of European geospatial datasets and a quasi-standard for LC/LU mapping in Europe.

The CLC2012 project represents the third update cycle in the history of CLC datasets, with precursors CLC1990, CLC2000 and CLC2006. All update phases have included the mapping of changes between the two reference dates.

The CLC2012 project is implemented within the framework of GMES Initial Operations continental component (GIO land). Pursuant to Regulation (EU) No 911/2010 on the European Earth monitoring programme (GMES) and its initial operations (2011 to 2013) and the delegation agreement signed between the EU and the European Environmental Agency (EEA), the coordination of the project was delegated to EEA. The CLC datasets (CLC2012 and CLC-Changes$_{2006\text{-}2012}$) are created by national teams (the Eionet National Reference Centres for spatial analysis and land cover – NRCs or their subcontractors) of the participating countries, founded via Grant Agreements signed between EEA and MS. 39 countries with a total area of 5.8 Mkm^2 participate in GIO Land Monitoring: 32 EEA member states and 7 cooperating countries (Table 1). Technical coordination (elaboration of guidelines, training of national teams, verification, technical support, provision of interpretation and checking software) is provided by the CLC Technical Team, ensuring the creation of thematically and technically harmonized results over Europe. This team consists of EEA and ETC-SIA[6] (from 2015 ETC-ULS[7]) experts.

[6] European Topic Center Spatial Information and Analysis

[7] European Topic Center Urban, Land and Soil Systems

Table 1 Participants of CLC2012 under GIO land

○ Albania ○ Austria ○ Belgium ○ Bosnia and Herzegovina ○ Bulgaria ○ Croatia ○ Cyprus ○ Czech Republic ○ Denmark ○ Estonia ○ Finland ○ Former Yugoslavian Republic of Macedonia ○ France ○ Germany ○ Greece ○ Hungary ○ Iceland ○ Ireland ○ Italy	○ Kosovo under UNSCR 1244/99 ○ Latvia ○ Liechtenstein ○ Lithuania ○ Luxemburg ○ Malta ○ Montenegro ○ The Netherlands ○ Norway ○ Poland ○ Portugal ○ Romania ○ Serbia ○ Slovakia ○ Slovenia ○ Spain ○ Sweden ○ Switzerland ○ Turkey ○ United Kingdom

4.1.2 Project phases

There are explicit project phases, however from a logical point of view the following processing steps can be defined:

- Preparatory phase
- Satellite image acquisition (ESA, EEA)
- Contracting (EEA)
- National production phase (National teams, CLC Technical Team:
    - CORINE Land Cover Change (2006-2012) mapping of all land cover changes between 2006 and 2012 with a spatial resolution of 5 ha for the standard 44 CORINE Land Cover classes. This includes the revision of CLC2006 dataset. (National Teams)
    - Two thematic verifications (with feedback loops) of CLC Changes and revised_CLC2006 datasets (CLC Technical Team).

  - Production of CORINE land cover map 2012, generalized to 25 ha minimum mapping unit. (National Team)
  - Technical checking of delivered products, i.e. CLC2012, CLC-Changes2006-2012, revised_CLC2006 (optional) (National Teams and ETC)
- European phase:
  - Creation of border-matched European products, including derived gridded data in 100m and 250m resolution. (EEA/ ETC-ULS)
  - Validation of European products (contracted Service provider)

4.1.3 Methods

The basic methodology of CLC production is described in detail in the CLC2006 Technical Guidelines (Büttner et. al 2007). According to this, CLC-Change$_{2006\text{-}2012}$ is the primary and most important product of the CLC2012 project. CLC-Change$_{2006\text{-}2012}$ is an individual product (i.e. not derived by intersecting CLC2006 and CLC2012) having a smaller MMU (5 ha) than CLC2006 and CLC2012 (25 ha). CLC-Change$_{2006\text{-}2012}$ is a European coverage of real land cover changes that

- are larger than 5 ha;
- wider than 100 m,
- occurred between 2006 and 2012;
- are detectable on satellite images
- represent a change between CLC classes;

regardless of their position (i.e. connected to existing CLC2006 polygon or being "island"-like).

The production is carried out by national teams, which combine best expertise with local knowledge, and access to national in-situ (ancillary) data. The overall thematic accuracy of the change database shall be >85 % (similarly to CLC2006).

Mapping of CLC changes is carried out by applying the 'change mapping first' approach, meaning that changes are interpreted directly, based on comparison of reference images. Changes are mapped by interpretation of visually detectable land cover differences on images from 2006 and 2012. As ancillary data, topographic maps, orthophotos, HRL, Google Earth imagery are used most frequently.

Delineation of changes is based on CLC2006 polygons in order to avoid creation of sliver polygons and false changes when producing CLC2012 database. Necessary thematic / geometric correction of CLC2006 data precedes the delineation of change polygons in order to avoid error propagation from CLC2006 to CLC2012. At the end of process CLC-Change$_{2006\text{-}2012}$ polygons are combined with CLC2006 polygons to obtain CLC2012 database.

Interpreter assigns two CLC codes to each change polygon: code2006 and code2012, both included as separate attributes. These codes represent the land cover status of the given polygon in the two dates respectively. Change code pair thus shows the process that occurred in reality and may be different from the codes occurring in the final CLC databases (due to generalisation applied in producing CLC2006 and CLC2012).

Most commonly used approaches to derive change data are computer-aided visual photointerpretation (CAPI) and semi-automatic approaches (merging of existing thematic datasets combined with sophisticated image processing techniques) (Büttner et al. 2013). The majority of countries apply CAPI in their CLC production, but there is an increasing number of semi-automated methods emerging to ensure synergy with national land monitoring initiatives.

4.1.4 Data model and nomenclature used

The nomenclature of CLC has remained practically unchanged since the beginning of project. The nomenclature includes 44 LU/LC classes, organized in three hierarchical levels and grouped into five major thematic areas.

Table 3: CLC nomenclature

1. ARTIFICIAL AREAS	1.1. Urban fabric	1.1.1. Continuous urban fabric
		1.1.2. Discontinuous urban fabric
	1.2. Industrial, commer-cial and transport units	1.2.1. Industrial, commercial, public and private units
		1.2.2. Road and rail networks and associated land
		1.2.3. Port areas
		1.2.4. Airports
	1.3. Mine, dump and construction sites	1.3.1. Mineral extraction sites
		1.3.2. Dump sites
		1.3.3. Construction sites
	1.4. Artificial non-agricultural vegetated areas	1.4.1. Green urban areas
		1.4.2. Sport and leisure facilities
2. AGRICULTURAL AREAS	2.1. Arable land	2.1.1. Non-irrigated arable land
		2.1.2. Permanently irrigated land
		2.1.3. Rice fields
	2.2. Permanent crops	2.2.1. Vineyards
		2.2.2. Fruit trees and berry plantations
		2.2.3. Olive groves
	2.3. Pastures	2.3.1. Pastures
	2.4. Heterogeneous agricultural areas	2.4.1. Annual crops associated with permanent crops
		2.4.2. Complex cultivation patterns
		2.4.3. Land principally occupied by agriculture with significant areas of natural vegetation
		2.4.4. Agro-forestry areas
3. FOREST AND	3.1. Forests	3.1.1. Broad-leaved forest
		3.1.2. Coniferous forest

SEMI-NATURAL AREAS		3.1.3. Mixed forest
	3.2. Shrubs and / or herbaceous vegetation associations	3.2.1. Natural grassland
		3.2.2. Moors and heathland
		3.2.3. Sclerophyllous vegetation
		3.2.4. Transitional woodland / shrub
	3.3. Open spaces with little or no vegetation	3.3.1. Beaches, dunes and sand planes
		3.3.2. Bare rock
		3.3.3. Sparsely vegetated areas
		3.3.4. Burntareas
		3.3.5. Glaciers and perpetual snow
4. WETLANDS	4.1. Inland wetlands	4.1.1. Inland marshes
		4.1.2. Peat bogs
	4.2. Coastal wetlands	4.2.1. Salt marshes
		4.2.2. Salines
		4.2.3. Intertidal flats
5. WATER BODIES	5.1. Inland waters	5.1.1. Water courses
		5.1.2. Water bodies
	5.2. Marine waters	5.2.1. Coastal lagoons
		5.2.2. Estuaries
		5.2.3. Sea and ocean

The nomenclature has detailed descriptive guidelines (Bossard et al. 2000). They have been updated and enhanced in 2013 in an ETC study (ETC-SIA IP2013 Task 261_2; see Kosztra and Arnold 2013) using the EAGLE principles (Arnold et al. 2013). The nomenclature has been developed for visual photo-interpretation, therefore classes often represent a pragmatic mixture of LC and LU information. A better separation of LC and LU information within class definitions was carried out within an ETC study (Task 2.2 - Semantic testing of project „Assistance to the EEA in the production of the new CORINE Land Cover (CLC) inventory), including the support to the harmonisation of national monitoring for integration at pan-European level[8]. The separation is executed by using the descriptive, decompository approach of the EAGLE concept (Kleeschulte et al. 2014).

4.1.5 Current usage of LUCAS

Similarly to the CLC2006 project[9], LUCAS data have been used as ancillary data in CLC2012 project in a non-harmonized manner. Use was restricted to the national phase of the project and was subject to decision of the implementing national team. According to the final GIO land reports

[8] Under Contract SC55998 based on the restricted procedure No EEA/MDI/14/012 following a call for expression of interest EEA/SES/13/005-CEI

[9] http://www.eea.europa.eu/data-and-maps/data/corine-land-cover/clc-final-report/clc-final-report

LUCAS (LC/LU information and field photos) has been used by the CLC implementing countries in the following ways:

- provided to photointerpreters as ancillary data to support and improve visual interpretation of landscape (Greece, Portugal, Norway[10])
- for quality assurance/quality control (Sweden)
- not specified (Finland, France, Romania, Slovakia).

The use of LUCAS data to validate the European CLC data was so far a one-time exercise, carried out in the CLC2000 project (Büttner and Maucha 2006).

4.2 High resolution layers (HRL)

4.2.1 Project background & Institutional setting

Strategic discussions amongst member countries, European Parliament and the main EU institutions responsible for environmental policy, reporting and assessment (DG ENV, EEA, EUROSTAT and JRC) have underlined an increasing need for factual and quantitative information on the state of the environment to be based on timely, quality assured data, in particular in land cover and land use related issues.

The technical coordination of the implementation of the pan-European and local component of the Copernicus land monitoring services is delegated to the EEA[11]. Information priorities and their relevance to users are defined and validated by the European Commission (EC) and the Copernicus committee, with the advice of the Copernicus User Forum.

The GIO land project, identified five land themes to be represented through the Pan-European High Resolution Layers (HRL). These layers shall provide information on specific land cover characteristics, and shall be complementary to the CORINE land cover (CLC) datasets. Setting 2012 as the reference year, the HRLs were produced from 20 m resolution satellite imagery. The ortho-rectified satellite input data for these layers was made available through the Copernicus satellite image Data Warehouse, set up by and hosted at the European Space Agency (ESA). The follow-

[10] Norway does not participate in LUCAS program, however, they produce a similar national variant of the survey: http://www.tandfonline.com/doi/abs/10.1080/00291951.2012.760001

[11] Pursuant to the Regulation (EU) No 911/2010 of the European Parliament and of the Council of 22 September 2010 on the European Earth Monitoring Programme (GMES) and its initial operations (2011 to 2013) and to the delegation agreement signed between the EC and the EEA,

ing HRL have been produced (or are still under production) through a combination of automatic processing and interactive rule based classification:

- Degree of Imperviousness (IMD)
- Tree cover density (TCD) and forest type (FTY),
- Permanent grasslands (GRA),
- Wetlands (WET)
- Permanent Water bodies (PWB).

4.2.2 Project phases

There are explicit project phases. However, from a logical point of view the following main processing steps can be defined:

- Preparatory phase
- Satellite image acquisition (ESA, EEA)
- Contracting (EEA)
- Production of intermediate HRLs (service providers, semantic check by ETC)
- Verification & error reporting (national teams / service providers, acceptance by EEA)
- Thematic layer enhancement (national teams / service providers, semantic check / correction by ETC)
- Integration and aggregation (service providers, semantic check by ETC)
- Creation of border-matched European products (service providers, semantic check by ETC)
- Validation of European products (service provider)
- Dissemination (EEA)

For all steps different protocols are available.

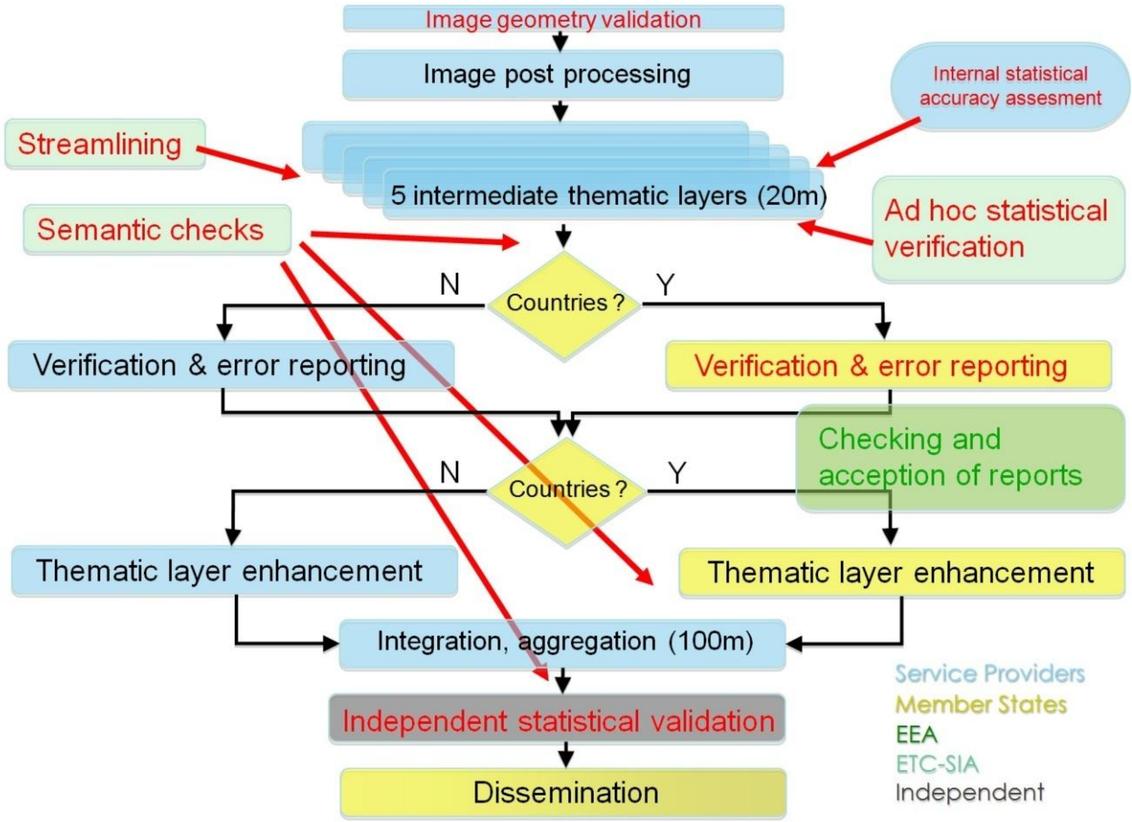


Figure 12: Overview of GIO land HRL 2012 workflow. Quality assessment steps are indicated in red.

4.3 HRL Grassland

4.3.1 Implementation status

The grassland layer has been produced under the EEA Framework Contract Nº EEA/SES/11/004-Lot 6 as part of the production of one of the five HRL. Due to the highly variable properties and definitions of grasslands across Europe, any grassland monitoring system faces considerable challenges. It was not surprising then, that there were major problems with the production and verification of this layer during its first iteration in 2012.

After reviewing the situation, EEA requested the production of a modified version of the grassland layer to be completed under GIO: the New Grassland (NGR) layer. Instead of trying to map all variations of grassland, the NGR concentrates on mapping semi-natural and natural grasslands. The NGR layer does not follow the project phases described in the previous chapter. After the production per country, the NGR layer directly went to the statistical validation phase and is currently in the phase of the final integration (mosaicking).

4.3.2 Methods

The production method of the NGR is based on an initial image segmentation followed by a visual image interpretation by remote sensing experts.

The analysis of the satellite imagery is based on

- Seasonal time series data (3-8 images with 4-6 week time intervals during the growing season);
- A multi-sensor concept, combining HR data with optimal spatial resolution (e.g. IRS-P6) with HR data of optimal temporal resolution (e.g. AWiFS).
- Utilisation of biophysical parameters derived from Image 2006 and Image 2009 for improved characterisation of the spatio-temporal behaviour of vegetation canopy.
- Object-oriented classification approach to provide efficient handling and analysis of multi-sensor/multi-scale data (i.e. 60 m AWiFS time series information and 20 m IRS/RapidEye), accurate definition and selection of training areas/data, flexible and efficient correction/enhancement of preliminary/final results by manual and automated procedures and homogenous classification result (no salt and pepper effect).
- Use of the robust C5.0 classifier. This classification algorithm does not require a normal distribution of the classes. Iit can handle missing values and automatically selects the relevant attributes for the classification. It further creates its own thresholds. So there is no need for adjusting parameters for each eco-region as long as they are adequately represented in the training data set. This is especially important in mountainous regions, where vegetation growth can be highly variable within a few kilometres.

4.3.3 Data model and nomenclature used

According to the EEA LOT 6 New Grassland Product definition the final HRL Grassland product specifications are:

- Semi-natural grassland (extensively managed) within forest, and grass covered surfaces within transitional woodland with low fraction (<10 %) of scattered trees and shrubs.
- Natural grassland in any environment.
- Grassy areas with low fraction (<10 %) of scattered trees and shrubs.
- Alpine meadows with low fraction (<30 %) of bare rock/gravel or shrubs.

The definition also extends to landscapes which are excluded from the final product:

- Intensively managed grassland.
- Pastures, grassland used for grazing or hay production (CLC class 231).
- Areas dominated by moors and heathland (Atlantic) or sclerophyllous vegetation (Mediterranean).
- Peatland (either in natural condition or in exploitation).
- Clear cut areas.
- Fruit trees, olive groves, vineyards and rice fields.
- Grasslands related to urban areas (airports, urban green areas and parks, sport and leisure areas, etc.).

- Surfaces covered predominantly by mosses and lichen (Subarctic).

Using as a reference the grassland definition of CLC, **Natural Grassland** (CLC 321) is defined as *low productivity grassland, often situated in areas of rough, uneven ground. Frequently includes rocky areas, briars and heathland.*

The New HRL Grassland (hereinafter referred to as NGR) product includes this definition taking into account the specifications mentioned above: only grasslands with less than 10 % cover of trees and/or shrubs will be included according to the specifications of the old HRL Grassland product[12]. In Alpine grasslands which are normally mixed with rocks, all grassland with rocks covering less than 30 % of the area will be included.

Pastures (CLC 231), are considered in general as improved and/or semi-improved grassland in the HRL Grassland definition, and therefore would NOT be included in the final product. It is considered as intensively managed grassland and therefore not natural nor semi natural.

Thematic pixel values for Permanent Water Layer

- 0: all non-NGR areas
- 1: semi-natural and natural grassland areas (NGR)
- 254: unclassifiable (no satellite image available, or clouds, shadows, or snow)
- 255: outside the production unit

Table 4: Comparison of new and old grassland specifications.

Landscape	New Definition of HRL Grassland	Old Definition of HRL Grassland	CLC
Natural Grassland in any surrounding	INCLUDED	INCLUDED	CLC 321
Semi-natural Grassland within forests, and grass covered surfaces within transitional woodland	INCLUDED	INCLUDED	CLC 311 CLC 312 CLC 313 CLC 324
Grassy Areas with low fraction (<10%) of scattered trees and shrubs	INCLUDED	INCLUDED	CLC 243 CLC 324

12 GIO land permanent grassland, wetland and water bodies: definitions and product specifications, lot 6, 2013-02-06. Page 9.

Landscape	New Definition of HRL Grassland	Old Definition of HRL Grassland	CLC
Alpine meadows with low fraction (<30%) of bare rock or gravel	INCLUDED	INCLUDED	CLC 321
Cultivated/managed grassland, pastures, grassland used for grazing or hay production	NOT INCLUDED	INCLUDED	CLC 231 CLC 211 to CLC 241
Olive groves, orchards and fruit plantations (when grassy cover fraction is dominant: >70%)	NOT INCLUDED	INCLUDED	CLC 223 CLC 222
Grasslands related to urban areas: airports, urban green areas and parks, sport and recreation areas	NOT INCLUDED	INCLUDED (in a separate layer)	CLC 141 CLC 142 CLC 122 CLC 124
Vineyards and rice fields	NOT INCLUDED	NOT INCLUDED	CLC 221 CLC 213
Shrub areas: areas dominated by moors and heathland (Atlantic) or sclerophyllous vegetation (Mediterranean)	NOT INCLUDED	NOT INCLUDED	CLC 322 CLC 323
Peatland (either in natural condition or in exploitation)	NOT INCLUDED	NOT INCLUDED	CLC 412
Surfaces covered predominantly by mosses and lichen (Subarctic).	NOT INCLUDED	NOT INCLUDED	CLC 333
Clear cut areas	NOT INCLUDED	NOT INCLUDED	CLC 324

4.3.4 Current usage of LUCAS

During the production process of the new grassland layer LUCAS data is used for the selection of training samples for the C5 classifier and as ancillary information during the visual interpretation /post-processing of the layer.

Furthermore, LUCAS data was used for the internal quality control by the service provider.

4.4 HRL Forest

4.4.1 Implementation status

The GIO forest layer has been produced under the EEA Framework Contract Nº EEA/SES/11/004 as part of the of five GIO High Resolution Layers (HRL) production.

4.4.2 Methods

The production of primary Copernicus tree cover / forest data may be separated to three key steps:

- Separation of tree covered / non tree covered area masks following inclusion & exclusion lists,
- Estimation of the tree cover density for each single 20m pixel within the tree covered area mask,
- Classification of tree covered pixels by leaf type (broadleaved / coniferous).

The initial separation of tree covered areas was performed via semi-automatic image classification methods based on the pre-defined land cover elements (Table 5).

Table 5: Elements to be included in / excluded from tree covered areas

Elements included in the tree covered area (GIO 2012)	Elements to be excluded from tree covered area (GIO 2012)
• Evergreen / non-evergreen broadleaved, sclerophyllous and coniferous trees • Orchards, olive groves, fruit and other tree plantations, agro-forestry areas, forest nurseries, regeneration, transitional woodlands • Alleys, wooded parks and gardens • Groups of trees within urban areas • Forest management/use features inside forests (forest roads, firebreaks, thinnings, etc.) - Included if tree cover can be detected from the 20m raster image pixel • Forest damage features inside forests (partially burnt areas, storm damages, insect-infested damages, etc.) - Included if tree cover can be detected from the 20m raster image pixel	• Open areas within forests (roads, permanently open vegetated areas, clear cuts, fully burnt areas, other severe forest damage areas, etc.) - Excluded if no tree cover can be detected from the 20m raster image pixels • Shrubland • Mediterranean bush lands (macchia, guarrigue etc.) • Dwarf pine / green alder in high-mountainous areas

A per-pixel classification of tree cover[13] density and of dominant leaf type (broadleaf, coniferous) was mapped in the frames of GIO land. Tree cover density values were calculated for pre-defined tree covered areas. Contrary to the tree cover density product non-forest trees were excluded following the FAO forest definition[14]. FAO defines forest areas based on the list shown in Table 6

Table 6: Elements to be included in / excluded from forest areas

Elements included in the forest area (GIO 2012)	Elements to be excluded from the forest area (GIO 2012)
• Forest nurseries and seed orchards that constitute an integral part of the forest • Forest roads, cleared tracts, firebreaks and other small open areas < 0.5 ha and/or < 20m width • Forest in national parks, nature reserves and other protected areas such as those of specific scientific, historical, cultural or spiritual interest • Windbreaks and shelterbelts of trees with an area of more than 0.5 ha and width of more or equal than 20 m • Plantations primarily used for forestry purposes, including cork oak stands • For the EEA purpose traditional agroforestry system such as Dehesa / Montado is included.	• Land predominantly used for agricultural practices - in this sense fruit trees and olive groves are also excluded • Gardens • Urban parks

In order to correspond largely to FAO definition, the 20m resolution forest type layer was derived in the practice following complex workflow:

- Classification of the TCD layer with tree cover densities from 0-100% as specified in the HRL Forest product specifications[15]
- Pixel values >= 10% and <= 100% are initially considered for the dominant leaf type layer. All pixels with a tree cover density value of < 10% were assigned to "non-tree area"

[13] "tree cover" is used instead of "crown cover" in view of compliance with the global land cover initiative (GEO)

[14] www.fao.org/docrep/006/ad665e/ad665e06.htm

[15] GIO land forest products: definitions and product specifications, Service Elements 1+2, Lots 1-5 V16. 2015-02-20. Publisher: GIO Land team at EEA.

- Application of a 4-pixel-connectivity MMU filter to “non-tree areas” <0.5ha: All “non-tree area” patches < 0.5ha are reclassified to “forest”. “Non-tree area” patches <0.5ha adjacent to (buffered) country borders can remain as they are (in case of country border-overarching production).
- Application of a 4-pixel-connectivity MMU filter to “tree-covered” areas <0.5ha: All “tree cover” patches <0.5ha are reclassified to “non-tree area”. “Forest” patches <0.5ha adjacent to (buffered) country borders can remain as they are (in case of country border-overarching production).
- Classification of the dominant leaf types (coniferous and broadleaved), for all pixels within the “forest mask” derived in steps 1-4. Pixels with an original tree cover density <10% that were previously assigned to “Forest” due to MMU filtering are classified according to the same spectrally-based classification algorithm rules as all other “Forest” pixels.

In an additional step, trees not used for forestry were identified based on CLC and the HRL Imperviousness data and documented in an additional support raster dataset. This support layer was used in the generalization process when aggregating 20m forest type product to 100m aggregated forest type product to exclude tree covered areas in agricultural / urban context.

Commission / omission errors of tree covered areas / forest type layer were identified and corrected during enhancement process.

4.4.3 Data model and nomenclature used

Final products are provided as raster datasets in compressed GeoTIFF format in national and European projections.

Thematic pixel values for Tree Cover Density Layer (20m / 100m resolution)

- 0: all non-tree covered areas
- 1-100: tree cover density values
- 254: unclassifiable (no satellite image available, clouds, shadows or snow)
- 255: outside the production unit

Thematic pixel values for Forest type layer (20m / 100m resolution)

- 0: non forest
- 1: broadleaved forest
- 2: coniferous forest
- 3: mixed forest (in aggregated 100m resolution only)
- 254: unclassifiable (no satellite image available, clouds, shadows or snow)
- 255: outside the production unit

Thematic pixel values for Additional support layer to Forest type (20m resolution only)

- 0: all non-tree areas
- 3: trees predominantly used for agricultural practices
- 4: trees in urban context (from HR Imperviousness Layer context)

- 5: trees in urban context – (from CLC class 1.4.1)
- 254: unclassifiable (no satellite image available, clouds, shadows or snow)
- 255: outside the production unit

4.4.4 Current usage of LUCAS

LUCAS 2012 data was used for the national verification of tree cover / leaf type in the case of France.

- TCD layers were compared to semantically aggregated class "woodland" (C00, containing all broadleaved / coniferous / mixed woodland classes: C10, C21, C22, C23, C31, C32, C33).
- FTY layers were compared with class "broadleaved woodland" (C10) and the semantically aggregated class "coniferous woodland" (C20, containing all coniferous woodland classes: C21, C22, C23)

LUCAS 2012 data was used for the internal accuracy assessment of tree cover / leaf type by one service provider (Planetek) in case of Greece, Italy, Portugal and Spain. LUCAS data were also used during the national verification[16].

- LUCAS 2012 attributes used: LC1, LC2, LC1_Species, LC1_Percent, Area_size
- LC classes used: All woodland classes for TCD (C00), broadleaved & coniferous woodland classes for FTY (C10, C20) + Fruit tree classes (B71..B77), "Olive groves" (B81), " Nurseries" (B83) and " Permanent industrial crops" (B84) together with LC1_Species field

4.5 HRL Imperviousness / Soil Sealing

4.5.1 Project background & institutional setting

Data and indicators on the extent and change in soil sealing or imperviousness (used synonymous) are important for a number of highly policy relevant issues. The GIO Imperviousness layer has been produced under the EEA Framework Contract Nº EEA/SES/11/004 as part of the production of one of the five GIO High Resolution Layers (HRL) and is currently in the phase of the final semantic checking, respectively the final European integration.

As predecessors, two pan-European coverages of imperviousness were produced in the frame of GMES (Copernicus) precursor activities and FP7 Geoland2 project

- “2006 soil sealing”[17]
- “imperviousness 2009”[18]

---

16 Intermediate Country Delivery Report - Spain - Forest. CDR_ES_FOR_V04. https://gaur.eea.europa.eu/gioland/report/209/download (not publicly available)

17 available at http://www.eea.europa.eu/data-and-maps/data/eea-fast-track-service-precursor-on-land-monitoring-degree-of-soil-sealing#tab-european-data

4.5.2 Methods

The following main steps make up the production line of HR Soil Sealing / Imperviousness layers:

- Separation of Built-up / Non built-up masks,
- Estimation of the degree of imperviousness (covered percentage of artificial surfaces) for each single 20m pixel within Built-up area mask.

The initial separation of built-up areas was performed via semi-automatic image classification methods based on the pre-defined land cover elements. Degree of imperviousness values were calculated on the basis of calibrated NDVI values.

In the case of the GIO imperviousness layer the commission / omission errors of the built-up areas were identified and corrected during enhancement process.

4.5.3 Data model and nomenclature used

The HRL Imperviousness product includes the following landscape types:

- Housing areas
- Traffic areas (airports, harbours, railway yards, parking lots)
- Industrial, commercial areas, factories
- Amusement parks (excluding the pure green areas associated with them)
- Construction sites with discernible evolving built-up structures
- Single (farm) houses (where possible to identify)
- Other sealed surfaces, which are part of fuzzy categories, such as e.g. allotment gardens, cemeteries, sport areas (visible infrastructure), camp sites (roads and infrastructure, possibly influenced by caravans), excluding green areas associated with them.
- Roads and railways associated to other impervious surfaces (no gaps manually filled, no roads manually digitized)
- Water edges with paved borders

Land cover not to be considered as impervious:

- Mines, quarries, peat production
- Dump sites
- Construction sites without discernible evolving built-up structures
- Meadows used for sports of any kind
- Bare soil, rock, sparsely vegetated areas
- Sand, sand pits

[18] Not publicly available yet, see http://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness/imperviousness-2009/view

- Glaciers, snow, water
- Railway lines

Final products are provided as raster datasets in compressed GeoTIFF format in national and European projections. Thematic pixel values for Imperviousness Layer (20m / 100m resolution):

- 0: all non-impervious areas
- 1-100: imperviousness values
- 254: unclassifiable (no satellite image available, or clouds, shadows, or snow)
- 255: outside the production unit

4.5.4 Current usage of LUCAS

LUCAS 2012 data was used for the national verification of the imperviousness layer in

- Cyprus - the Imperviousness layer has been compared with Lucas 2012 dataset as part of general overview
- France – Imperviousness layer has been compared to BD LUCAS 2012, by selecting 919 points into “Artificial land” theme.
- In Slovakia LUCAS 2012 data was used both verification and enhancement (no detail about way of use).

LUCAS 2012 data was used for the internal accuracy assessment of impervious areas by one service provider (Planetek) in case of Portugal and Spain.

4.6 HRL Wetlands

4.6.1 Implementation status

The GIO Wetlands layer (or better defined as Wetness layer) has been produced under the EEA Framework Contract Nº EEA/SES/11/004 as part of the production of one of the five GIO High Resolution Layers (HRL) and is currently in the phase of the final semantic checking, respectively the final European integration.

4.6.2 Methods

Wetlands in the original tender specifications[19] for the GIO HRL on wetlands are defined on basis of the following criteria:

Wetlands include the following landscape types:

[19] Technical Annex to Specific Contract Nº 3541/B2012/R0-GIO/EEA 54870 implementing Framework Contract Nº EEA/SES/11/004-Lot 6

- Wetlands associated to permanent water bodies
- Wetlands not associated to permanent water bodies
- Wetlands with vegetation (macrophyte) cover or without vegetation
- Peatlands (having presence of surface water)
- Coastal wetlands (salt marshes, salines, intertidal flats)

Land cover types not to be considered as wetlands:

- temporary water-logging because of snow melt or heavy rains
- permanent water surfaces (rivers, lakes, lagoons, estuaries, fish ponds)
- wet agricultural fields, including rice fields

These criteria were translated into a production workflow which mainly built on the presence of water in a given satellite image pixel. While pixels with permanent water presence were classified as “permanent water body”, pixels with non-permanent (temporary) presence of water were classified as “wetlands”.
Input data for this workflow were high resolution (HR) satellite images of IMAGE 2012 (coverage 1 and coverage 2) and multi-temporal AWIFS images.
Details on the methodology, the thresholds for separating water and wetland pixels and other company contain internal IPR issues and should be requested directly from the EEA or the service provider.
Water and wetland production is carried out within one automated work-flow. After pre-processing of satellite images and computing of biophysical parameters, classification of binary water and wetlands masks out of all available HR satellite images is performed. The next step of production is the iterative accumulation of values (0 – no mask; 1 - mask present) of binary image masks, water masks and wetland masks, followed by computing of water/image and wetland/image ratio values (0…1), thus producing the Water Presence Index (WAPI) and Wetlands Presence Index (WEPI) layers. The final step of production is the re-coding of WAPI and WEPI layers into the thematic binary products - Permanent Water Layer (PWAL) and Permanent Wetlands Layer (PWEL).

4.6.3 Data model and nomenclature used

The table shows the product specifications for the Wetland HRL (HRL WET) as defined by SP and EEA. The HRL WET is a raster database of 20m*20m. The nomenclature of the HRL consists of thematic pixel values for non-wetland (0) and wetland (1), unclassifiable pixels (254) and pixels outside the production unit (255).

Wetlands	
Wetland *(based on 2006-2009-2012 data)*	*Wetland 20m is binary, mapping wetlands/non-wetlands in national projection*
	Wetland 100m is occurrence of wetland (0-100%) in LAEA projection
Methodology	

To solve the problem of mapping seasonal development of macrophyte vegetation communities covering water bodies, we developed a concept of Wetland Presence Index (WEPI). Instead of subjective selection of one particular wetland classification from one satellite image, we will compute a floating index (0...1) based on frequency of wetland occurrence across the whole time-series of satellite images. The main objective will be identification of areas with constant presence of wetlands – the statistical water/wetland frequency index"

"permanent wetland" layer - characterised by the highest ratio of wetland/image values. The residual areas with wetland/image ratio ranging from low to medium values will be classified as "temporary wetland", while all other values will be eliminated as accidental findings or classification errors. Wetlands will be classified primarily based on the presence of water, therefore "temporary water" areas will become an essential part of Wetlands products.

Classification of satellite imagery is based on:

- *Seasonal time series of HR images (3-8 images with 4-6 weeks time interval, including both Coverages 1 and 2);*
- *Utilisation of ancillary layers provided by recent GMES projects (EU-DEM, EU-HYDRO, Soil Sealing 2009) as spatial filters and masks in the production work-flow;*
- *Utilisation of biophysical parameters produced from IMAGE 2006/2009/2012 HR imagery;*
- *Utilisation of Wetlands Distribution Support Layers (WDSL) containing ranges of biophysical parameters computed from the time-series of 2011/2012 AWIFS images;*
- *Automated extraction of wetland pixels as binary masks from a time-series of High Resolution satellite images;*
- *Computing of a per-pixel Wetland Presence Index (WEPI) containing values of wetland detection frequency (ratio $N_{wetland} / N_{images}$);*
- *Post-processing of Wetland product (WEPI) into a Permanent Wetland Layer (PWEL).*

A series of intermediate products will be archived for delivery upon request. Those will include separate binary classified image masks, layers containing per-pixel values of Sum of Image Masks and Sum of Wetland Masks, also processing masks for separate images. Separate layers containing per-pixel threshold values (depending of the number of images processed)

used for post-processing of WEPI layer into PWEL will be archived as well.		
Geometric resolution		
Pixel resolution 20m x 20m, MMU – 1 pixel		
Coordinate Reference System		
National projection systems for country data sets		
Geometric accuracy (positioning scale)		
According to ortho-rectified satellite imagery delivered by ESA		
Thematic accuracy of Wetland products (in %)		
80%		
Data type/format		
Raster GEOTIF		
Product	Year	Classification
Wetland Inventory (20m x 20m, national and European projections) Wetland Inventory (100m x 100m (1ha) European projection)	2012 2012	Wetland – Non-Wetland seasonal variation (degree of wetness classes) Wetland – Non-Wetland seasonal variation (degree of wetness classes)
Raster coding		
Thematic pixel values for Permanent Wetland Layer *0: all non-wetland areas* *1: wetland* *254: unclassifiable (no satellite image available, or clouds, shadows, or snow)* *255: outside the production unit*		
Metadata		
According to INSPIRE metadata standards		

4.6.4 Current usage of LUCAS

LUCAS data are used as one of the data sources to create a database of reference points for the verification of the production results (omissions/commissions).

4.7 HRL Water bodies

4.7.1 Implementation status

The water layer has been procured under EEA Framework Contract Nº EEA/SES/11/004-Lot 6 as part of the production of one of the five HRL and is currently finalising the semantic checks before entering the final European integration (mosaicking).

.

4.7.2 Methods

The HRL "permanent water" was produced in one automated work flow together with the HRL wetlands. After pre-processing of satellite images and computing of biophysical parameters, classification of binary water and wetlands masks out of all available HR satellite images have been performed. The next step of production has been an iterative accumulation of values (0 – no mask; 1 - mask present) of binary image masks, water masks and wetland masks, followed by computing of water/image and wetland/image ratio values (0…1), thus producing the Water Presence Index (WAPI) and Wetlands Presence Index (WEPI) layers. The final step of production encompassed the re-coding of WAPI and WEPI layers into the thematic binary products - Permanent Water Layer (PWAL) and Permanent Wetlands Layer (PWEL).

Classification of satellite imagery is based on:

- Seasonal time series of HR images (3-8 images with 4-6 weeks time interval, including both Coverages 1 and 2);
- Utilisation of ancillary layers provided by recent GMES projects (EU-DEM, EU-HYDRO, imperviousness 2009) as spatial filters and masks in the production work-flow;
- Utilisation of biophysical parameters produced from IMAGE 2006/2009/2012 HR imagery;
- Automated extraction of water pixels as binary masks from a time-series of High Resolution satellite images;
- Computing of a per-pixel Water Presence Index (WAPI) based on the *ratio* N_{water} / N_{images}
- Post-processing of the WAPI into the Permanent Water Layer (PWAL)

4.7.3 Data model and nomenclature used

According to the EEA LOT 6 Water definition the final product specifications include the following types:

Water includes the following landscape types:

- Permanent lakes, ponds (artificial and man-made) including fish ponds
- Rivers, channels permanently with water
- Coastal water surfaces: lagoons, estuaries

Land covers not to be considered as water are:

- Sea and ocean
- Liquid dump sites

Thematic pixel values for the Permanent Water Layer raster products are

- 0: all non-water areas
- 1: water
- 254: unclassifiable (no satellite image available, or clouds, shadows, or snow)
- 255: outside the production unit

4.7.4 Current usage of LUCAS

LUCAS information is not used during the automated production process of the water layer. LUCAS data was used for the internal quality control by the service provider. However, no further information on the exact use was available to the authors.

4.8 Local component: Urban Atlas

4.8.1 Project background & institutional setting

The Urban Atlas is a joint initiative of DG REGIO and the DG Enterprise with the support of the ESA and the EEA. It was developed in the context of the geoland-2 project and its implementation was tendered out in 2009, but is now part of the Copernicus “local component”, procured directly by DG REGIO.

4.8.2 Implementation status

The first phase of the Urban Atlas was launched in 2009, went through 2011 and included the mapping of some 305 urban areas with more than 100.000 inhabitants. The image database used for mapping was IMAGE2006 data with 2.5m resolution[20].

In its second round, using IMAGE2012, the Urban Atlas was enlarged to encompass some 795 urban areas, with more than 50.000 inhabitants. Production of the 2012 layer is on-going.

4.8.3 Methods

The mapping of the Urban Atlas is based on automated image processing in combination with visual post-processing. The production involves existing data on road networks and the Copernicus HRL on imperviousness as two important input parameters.

While the 2006 Urban Atlas data used commercial-off-the-shelf (COTS) navigation data (i.e. Tele-Atlas), the 2012 version uses freely available data from OpenStreetMap (OSM) to identify the road network.

Major production steps include:

- Automated segmentation and classification to achieve an initial differentiation between basic land cover classes (urban vs. forest vs. water vs. other land cover);
- As the backbone for the object geometry, the COTS navigation data network is recommended;

[20] available at http://www.eea.europa.eu/data-and-maps/data/urban-atlas#tab-gis-data

- The delineation is to be done on the EO data. EO data should be considered as the primary (guiding) data source.
- The Copernicus imperviousness layer is used for classification of the sealing densities of class 1.1 urban fabric in level 3 and level 4.

The product has two different minimum mapping units:

- 0.25 ha for class 1
- 1 ha for class 2 to 5

4.8.4 Data model and nomenclature used

Table 7: UA nomenclature (in bold: classes without any further subdivision)

Urban Atlas No.	Vector Data Code	Nomenclature	Additional Information
1		Artificial surfaces	
1.1		Urban Fabric	
1.1.1	**11100**	**Continuous Urban Fabric (S.L. > 80%)**	**GIO HRL imperviousness required**
1.1.2	11200	Discontinuous Urban Fabric (S.L. 10% - 80%)	
1.1.2.1	**11210**	**Discontinuous Dense Urban Fabric (S.L. 50% - 80%)**	**GIO HRL imperviousness required**
1.1.2.2	**11220**	**Discontinuous Medium Density Urban Fabric (S.L. 30% - 50%)**	**GIO HRL imperviousness required**
1.1.2.3	**11230**	**Discontinuous Low Density Urban Fabric (S.L. 10% - 30%)**	**GIO HRL imperviousness required**
1.1.2.4	**11240**	**Discontinuous Very Low Density Urban Fabric (S.L. < 10%)**	**GIO HRL imperviousness required**
1.1.3	11300	Isolated structures	
1.2		Industrial, commercial, public, military, private and transport units	
1.2.1	**12100**	**Industrial, commercial, public, military and private units**	**zoning data/ field check recommended**
1.2.2	12200	Road and rail network and associated land	COTS navigation data required

Urban Atlas No.	Vector Data Code	Nomenclature	Additional Information
1.2.2.1	12210	Fast transit roads and associated land	COTS navigation data required
1.2.2.2	12220	Other roads and associated land	COTS navigation data required
1.2.2.3	12230	Railways and associated land	COTS navigation data required
1.2.3	12300	Port areas	zoning data / field check recommended
1.2.4	12400	Airports	zoning data / field check recommended
1.3		Mine, dump and construction sites	
1.3.1	13100	Mineral extraction and dump sites	
1.3.3	13300	Construction sites	
1.3.4	13400	Land without current use	
1.4		Artificial non-agricultural vegetated areas	
1.4.1	14100	Green urban areas	
1.4.2	14200	Sports and leisure facilities	
2	20000	Agricultural areas	1 ha MMU
2.1	21000	Arable land (annual crops)	
2.2	22000	Permanent crops	
2.3	23000	Pastures	
2.4	24000	Complex and mixed cultivation patterns	
2.5	25000	Orchards	
3	30000	Natural and (semi-)natural areas	1 ha MMU
3.1	31000	Forests	
3.2	32000	Herbaceous vegetation associations	
3.3	33000	Open spaces with little or no vegetations	

Urban Atlas No.	Vector Data Code	Nomenclature	Additional Information
4	40000	Wetlands	1 ha MMU
5	50000	Water	1 ha MMU

4.8.5 Current usage of LUCAS

LUCAS data has not been directly used for the Urban Atlas, due to the stratification which favours rural areas, but the LUCAS sampling scheme was used as a basis to develop the service provider's internal validation procedure.

4.9 Local component: riparian zones

4.9.1 Project background & institutional setting

The specific areas of interest for this local component are the riparian zones, the interface between land and a river, stream, lake or sea where detailed and harmonised information is missing across the EU, filling a gap that GMES/Copernicus had not yet addressed, i.e. biodiversity. It also reflects an increasing awareness of the ecological and economic importance of riparian zones with its focus on ecosystem services.

From a policy perspective, the choice for the riparian zones is underpinned by the objectives of several legal acts and policy initiatives in the environmental domain, to mention a few:

- Link with the EU Biodiversity Strategy to 2020, in particular target 2, on mapping and assessing ecosystems and their services, green infrastructure and restoration;
- Link with the Nature Directives (Habitats and Birds Directives) and target 1 of the EU Biodiversity Strategy to 2020;
- Link with the management of river basins in line with the Water Framework Directive (WFD);
- Link with the flood protection measures in the Floods Directive;
- Link with the new initiative on Maritime Spatial Planning and Integrated Coastal Management.

The service shall be designed in such a way that it delivers usable information for the Mapping and Assessment of Ecosystems and their services (MAES), the Green Infrastructure and its restoration objectives (in accordance with target 2 of the EU biodiversity strategy to 2020). This requires in particular the mapping of features which are crucial for ecosystem condition and the delivery of ecosystem services. It shall also enable future land cover change detection suitable for the EEA land accounts.

This Copernicus land service will serve as a basis for habitat and biodiversity monitoring and in support of the MAES exercise. Future exercises, repeated in policy-relevant intervals, are meant to analyse changes in land use and its influence on land cover, which is a major factor in the distribution and functioning of ecosystems and in the delivery of ecosystem services.

The overall service for the production of the riparian zones mapping is split into three components:

- Delineation of riparian zones
- Production of Land Cover and Land Use along a buffer zone of selected rivers
- Green linear elements

They can be executed almost in parallel and with a minimum of interdependencies, rather than sequentially. Each part of the service yields a separate VHR data layer. Nevertheless, it is obligatory that consistency and coherence between the 3 components be maintained. Green linear elements are detected in the same area as the LU/LC product.

4.9.2 Implementation status

The project has to deliver the following three products:

- Production of LU/LC along a buffer zone of selected rivers
- Delineation of riparian zones
- Green linear elements

The production takes place under Copernicus Initial Operations 2011-2013. Land Monitoring Service Local Component: Riparian Zones. An accuracy assessment is part of each of the production lines for the mentioned products.

4.9.3 Methods

The following steps can be discerned in the production of the three Riparian Zone components:

LU/LC along a buffer zone of selected rivers[21]

- Skeletonisation
- Segmentation and automatic pre-classification
- Visual interpretation

[21] Riparian_Zones_Technical_Proposal_v1_0

- MAES level 3 and level 4 attribution[22]
- Quality assurance checks

Delineation of riparian zones

- Stratification
- Calculation of the potential riparian zones
- Calculation of the observable riparian Zone
- Final segmentation and aggregation of membership values to derive riparian zones
- Quality assessment approach

Green linear elements (GLE)

- Data preparation
- Pre-classification of GLE candidates
- Visual image interpretation
- Geometric generalization and post-processing
- Reconciliation with the VHR LC/LU product
- Quality assurance and product finalization

4.9.4 Data model and nomenclature used

LU/LC along a buffer zone of selected rivers

Vector data set with polygons classified according the MAES level 3- 4 nomenclature.

[22] >80 LU/LC classes according to “Nomenclature of the Land Cover and Land Use Product v2.1” issued 18.09.2014, not publicly available

The Riparian Zone LU/LC classes (v2.1 issued 18.09.2014)

Level 1	Level 2	Level 3	Level 4	Attribute T.C.D. Forest	UA Attribute	Relation to EUNIS
1 Urban	1.1 Urban fabric, industrial, commercial, public, military and private units	1.1.1 Dense to medium dense urban fabric (IM.D. >30-100% + industrial, commercial, public, military and private units)	1.1.1.1 Continuous urban fabric (in-situ based or IM.D. >80-100%)			J1.1, J1.2, J1.3, J1.4, J1.5, J.1.7, J4.6, X22, X24, X25
			1.1.1.2 Dense urban fabric (IM.D. >30-80% + industrial, commercial, public, military and private units)			J1.1, J1.2, J1.3, J1.4, J1.5, J.1.7, J4.6, X22, X23, X24, X25
			1.1.1.3 Industrial or commercial units			J1.4, J4.7
		1.1.2 Low density urban fabric (IM.D. 0-30%)	1.1.2.1 Low density urban fabric (IM.D. 0-30%)			J2.1, J2.2, J2.3, J2.4, J2.5, J2.6, J2.7
	1.2 Transport infrastructure	1.2.1 Transport infrastructure	1.2.1.1 Road networks and associated land			J4.1, J4.2
			1.2.1.2 Railways and associated land			J4.3
			1.2.1.3 Port areas			J4.5
			1.2.1.4 Airports			J4.4
	1.3 Mineral extraction, dump and construction sites, land without current use	1.3.1 Mineral extraction, dump and construction sites	1.3.1.1 Mineral extraction, dump and construction sites			J3.2, J3.3
		1.3.2 Land without current use	1.3.2.1 Land without current use			
	1.4 Green urban, sports and leisure facilities	1.4.1 Green urban areas	1.4.1.1 Green urban areas T.C.D. ≥ 30%			X11, X23, I2
			1.4.1.2 Green urban areas T.C.D. < 30%			X11, X23, I2
		1.4.2 Sports and leisure facilities	1.4.2.1 Sports and leisure facilities T.C.D. ≥ 30%			
			1.4.2.2 Sports and leisure facilities T.C.D. < 30%			
2 Croplands	2.1 Arable land	2.1.1 Non-irrigated arable land	2.1.1.1 Non-irrigated arable land			I1.11, I1.12, I1.13, I1.21, I1.22, I1.3, I1.51, I1.52, I1.53
		2.1.2 Greenhouses	2.1.2.1 Greenhouses			I1.13, I1.22, J2.43
		2.1.3 Irrigated arable land and rice fields	2.1.3.1 Irrigated arable land and rice fields			I1.4, I1.54, I1.55
		2.1.4 Complex patterns of irrigated and non-irrigated arable land	2.1.4.1 Complex patterns of irrigated and non-irrigated arable land			I1
Level 1	**Level 2**	**Level 3**	**Level 4**	**Attribute T.C.D. Forest**	**UA Attribute**	**Relation to EUNIS**
	2.2 Permanent crops	2.2.1 Vineyards	2.2.1.1 Vineyards			FB.41, FB.42
		2.2.2 Fruit trees and berry plantations	2.2.2.1 High stem fruit trees (extensively managed)			G1.D4, G2.92, G1.D5
			2.2.2.2 Low stem fruit trees and berry plantations			FB.31, G2.94
		2.2.3 Olive groves	2.2.3.1 Olive groves			G2.91 X06
	2.3 Heterogeneous agricultural area	2.3.1 Annual crops associated with permanent crops	2.3.1.1 Annual crops associated with permanent crops			I1
		2.3.2 Complex cultivation patterns	2.3.2.1 Complex cultivation patterns			I1
		2.3.3 Land principally occupied by agriculture with significant areas of natural vegetation	2.3.3.1 Land principally occupied by agriculture with significant areas of natural vegetation			I1, X07, X10
		2.3.4 Agro-forestry T.C.D. ≥ 30%	2.3.4.1 Agro-forestry T.C.D. ≥ 30%			E7.3, X06
		2.3.5 Agro-forestry T.C.D. < 30%	2.3.5.1 Agro-forestry T.C.D. < 30%			E7.3, X06
3 Woodland and forest	3.1 Broadleaved forest	3.1.1 Riparian and fluvial Broadleaved forest	3.1.1.1 Riparian and fluvial Broadleaved forest	T.C.D. > 80%, > 50 - 80%, > 30 - 50%, ≥ 10 - 30%		G1.1 – G1.3
		3.1.2 Broadleaved swamp forest	3.1.2.1 Broadleaved swamp forest	T.C.D. > 80%, > 50 - 80%, > 30 - 50%, ≥ 10 - 30%		G1.4, G1.5
		3.1.3 Other natural & semi natural broadleaved forest	3.1.3.1 Other natural & semi natural broadleaved forest	T.C.D. > 80%, > 50 - 80%, > 30 - 50%, ≥ 10 - 30%		G1.6, G1.7, G1.8, G1.9, G1.A, G1.B
		3.1.4 Broadleaved evergreen forest	3.1.4.1 Broadleaved evergreen forest	T.C.D. > 80%, > 50 - 80%, > 30 - 50%, ≥ 10 - 30%		G2
		3.1.5 Highly artificial broadleaved plantations	3.1.5.1 Highly artificial broadleaved plantations	T.C.D. > 80%, > 50 - 80%, > 30 - 50%, ≥ 10 - 30%		G1.C
	3.2 Coniferous forest	3.2.1. Riparian and fluvial coniferous forest	3.2.1.1 Riparian and fluvial coniferous forest	T.C.D. > 80%, > 50 - 80%, > 30 - 50%, ≥ 10 - 30%		

Level 1	Level 2	Level 3	Level 4	Attribute T.C.D. Forest	UA Attribute	Relation to EUNIS
		3.2.2 Coniferous swamp forest	3.2.2.1 Coniferous swamp forest	T.C.D. > 80%, > 50 - 80%, > 30 - 50%, ≥ 10 - 30%		G3.D
		3.2.3 Other natural & semi natural coniferous forest	3.2.3.1 Other natural & semi natural coniferous forest	T.C.D. > 80%, > 50 - 80%, > 30 - 50%, ≥ 10 - 30%		G3
		3.2.4 Highly artificial coniferous plantations	3.2.4.1 Highly artificial coniferous plantations	T.C.D. > 80%, > 50 - 80%, > 30 - 50%, ≥ 10 - 30%		G3.F
		3.3.1.Riparian and fluvial mixed forest	3.3.1.1 Riparian and fluvial mixed forest	T.C.D. > 80%, > 50 - 80%, > 30 - 50%, ≥ 10 - 30%		
		3.3.2 Mixed swamp forest	3.3.2.1 Mixed swamp forest	T.C.D. > 80%, > 50 - 80%, > 30 - 50%, ≥ 10 - 30%		G4.1
		3.3.3 Other natural & semi natural mixed forest	3.3.3.1 Other natural & semi natural mixed forest	T.C.D. > 80%, > 50 - 80%, > 30 - 50%, ≥ 10 - 30%		G4
		3.3.4 Highly artificial mixed plantations	3.3.4.1 Highly artificial mixed plantations	T.C.D. > 80%, > 50 - 80%, > 30 - 50%, ≥ 10 - 30%		G4.F

Level 1	Level 2	Level 3	Level 4	Attribute T.C.D. Forest	UA Attribute	Relation to EUNIS
	3.4 Transitional woodland scrub	3.4.1 Transitional woodland scrub	3.4.1.1 Transitional woodland and scrub			G5.6, G5.7, G5.8
			3.4.1.2 Lines of trees and scrub			G5.1
	3.5 Damaged forest	3.5.1 Damaged forest	3.5.1.1 Forest damaged by fire			
			3.5.1.2 Other damaged forest			
4 Grassland	4.1 Managed grassland	4.1.1 Managed grassland	4.1.1.1 Managed grasslands with trees and scrubs (T.C.D. ≥ 30%)			
			4.1.1.2 Managed grasslands without trees and scrubs (T.C.D. < 30%)			
	4.2 Natural grasslands *(N.B.: adjusted class name due to evident mistake in tender nomenclature)*	4.2.1 Natural grasslands prevailingly with trees and scrubs	4.2.1.1 Dry grasslands with trees (T.C.D. ≥ 30%)			E1, E6
			4.2.1.2 Mesic grasslands with trees (T.C.D. ≥ 30%)			E2, E3, E5, B1.19
		4.2.2 Natural grasslands without trees and scrubs	4.2.2.1 Dry grasslands without trees (T.C.D. < 30%)			E1
			4.2.2.2 Mesic grasslands without trees (T.C.D. < 30%)			E2, E3
			4.2.2.3 Alpine and subalpine grasslands without trees (T.C.D. < 30%)			E.4
5 Heathland and scrub	5.1 Moors and heathland	5.1.1 Moors and heathland	5.1.1.1 Heathlands and Moorlands			F1, F3, F4, F8, F9
			5.1.1.2 Other scrub land			F2
	5.2 Sclerophyllous vegetation	5.2.1 Sclerophyllous vegetation	5.2.1.1 Sclerophyllous vegetation			F5, F6, F7
6 Sparsely vegetated land	6.1 Sparsely vegetated areas	6.1.1 Sparsely vegetated areas	6.1.1.1 Sparsely vegetated areas			H5.22, H5.31, H5.32, H5.4
	6.2 Bare soil, rock, perennial snow & ice	6.2.1 Beaches, dunes, sands	6.2.1.1 Beaches			B1.1, B1.2
			6.2.1.2 Dunes			B1.3, B1.4, H5.33, H5.34
			6.2.1.3 River banks			C3.6, C3.7
		6.2.2 Bare rocks, burnt areas, glaciers and perpetual snow	6.2.2.1 Bare rocks and rock debris			H2, H3, H5.21, H5.35, H5.36, H5.37, H6
			6.2.2.2 Burnt areas (except burnt forest)			H5.5
			6.2.2.3 Glaciers and perpetual snow			H4
7 Wetland	7.1 Inland marshes	7.1.1 Inland freshwater marshes	7.1.1.1 Inland freshwater marshes without reeds			
			7.1.1.2 Inland freshwater marshes with reeds			

Level 1	Level 2	Level 3	Level 4	Attribute T.C.D. Forest	UA Attribute	Relation to EUNIS
		7.1.2 Inland saline marshes	7.1.2.1 Inland saline marshes without reeds			
			7.1.2.2 Inland saline marshes with reeds			
	7.2 Peat bogs	7.2.1 Peat bogs	7.2.1.1 Exploited peat bog			X04
			7.2.1.2 Unexploited peat bog			X04, X28
8 Lagoons, coastal wetlands and estuaries	8.1 Maritime wetlands	8.1.1 Salt marshes & salines	8.1.1.1 Salt marshes without reeds			C1.5
			8.1.1.2 Salt marshes with reeds			C1.5
			8.1.1.3 Salines			J5.11
		8.1.2 Intertidal flats	8.1.2.1 Intertidal flats			A1, A2.1,A2.2, A2.3, A2.4
	8.2 Marine waters	8.2.1 Coastal lagoons	8.2.1.1 Coastal lagoons without reeds			C3, X02
			8.2.1.2 Coastal lagoons with reeds			C3, X02
		8.2.2 Estuaries	8.2.2.1 Estuaries			X01
9 Rivers and lakes	9.1 Water courses	9.1.1 Interconnected running water courses	9.1.1.1 Permanent interconnected running water courses			C2.2
			9.1.1.2 Intermittently running water courses			C2.5
			9.1.1.3 Highly modified natural water courses and canals			J5.41
		9.1.2 Separated water bodies belonging to the river system (dead side-arms, flood ponds)	9.1.2.1 Permanent separated water bodies belonging to the river system			C1.1, C1.2, C1.3, C1.4, C1.5
			9.1.2.2 Temporary separated water bodies belonging to the river system			C1.6
	9.2 Lakes and reservoirs	9.2.1 Lakes and reservoirs	9.2.1.1 Permanent natural water bodies			C1.1, C1.2, C1.3, C1.4, C1.5
			9.2.1.2 Temporary natural water bodies			C1.6
			9.2.1.3 Ponds and lakes with completely man-made structure			J5.31, J5.33
			9.2.1.4 Intensively managed fish ponds			J5.32
			9.2.1.5 Standing water bodies of extractive industrial sites			J5.34
10 Marine (other)	10.1 Marine (other)	10.1.1 Marine (other)	10.1.1.1 Marine (other)			A

Delineation of riparian zones

Vector dataset of the delineation of riparian zones with the associated INSPIRE compliant meta-data. The nomenclatures consist of two classes: riparian zones and non-riperian zones.

Green linear elements

Vector dataset with green linear elements with the associated INSPIRE compliant metadata. There are three classes within the GLE product: trees, scrub/hedgerows (both as patches or linear elements) and non-GLE. Trees are defined according to the FAO definition, which guarantees consistency with other Copernicus Land data. The definition of the GLE is the following:

Product Definition
The GLE product provides a very high resolution data layer of at least 85% overall thematic accuracy at pan-European scale comprising • vegetated linear structures such as hedgerows, scrubs or tree rows with a width of 10m or smaller, as well as • isolated patches of trees and scrub with a size of 500m² to 5000m², i.e. smaller than the minimum mapping unit of the LC/LU layer. All characteristics are mapped as identifiable from 1.5m to 2.5m DWH CORE_03 satellite imagery The Area of Interest is identical to the LC/LU product. **Thematically**, a breakdown into hedgerows/scrub as well as trees is provided. Trees are defined according to the FAO definition, i.e. reaching a minimum height of 5 m at maturity in situ, which guarantees consistency with other Copernicus data, such as the HRL Forest. Hedgerows/scrub are defined as woody perennial plants, generally of more than 0.5m and less than 5 m height, and often without a definite stem and crown. GLEs exclude grassy elements (e.g. margins along field boundaries), wet elements (drainage ditches, water courses) or artificial elements (any kind of 'grey' infrastructure such as roads or stone walls). Besides the thematic classification, a very distinct **geometric** separation into linear structures as well as areal patches is done. This differentiation takes place by considering a compactness criterion, resulting in a distinct separation of linear structures (low compactness) and patches (high compactness). • Linear structures are characterized by a linear shape (object with low compactness and a circularity below or equal 0.3) and are defined by a width below or equal 10m and a length above or equal 100m. A minimum mapping area criterion is not applied to the linear structures. Hence, features may be <500m² (if very thin <5m) or >5,000m² (if very long >1,000m). • Patches are characterized by a non-linear shape (object with high compactness and a circularity above 0.3) and are defined by a minimum mapping area between 500m² and 5,000m² and a width above or equal 10m. A minimum length criterion is not applied. Due to the absence of data on vegetation height, the thematic separation into trees and hedgerows/scrubs is only possible using the planimetric satellite imagery, which causes a certain ambiguity in the differentiation of those features (i.e. if these are smaller or higher than 5m).

4.9.5 Current usage of LUCAS

According to the service provider in charge of the riparian zone products, the internal accuracy assessment will most likely not use LUCAS since it is believed to not provide a suitable sampling scheme and a sufficient thematic complementarity to the MAES-based product nomenclature.

5 Linking the LUCAS and Copernicus land monitoring programme

5.1 Programme frameworks

5.1.1 ESA image acquisition[23]

All land monitoring services depend on regularly updated satellite image data covering the EU member states land surface. Before Copernicus, such European image mosaics were generated to serve the CLC mapping as interpretation and analysis data source:

- Image 2000: Landsat 7 images (from 1999-2001)
- Image 2006: SPOT 4, SPOT 5 and IRS-P6 images (2005-2007)
- Image 2009: majority of IRS-P6/ResourceSat-1 with gap filling by SPOT-4/-5

To meet the higher demands of Copernicus[24], the Copernicus space component was established. It encompasses the Sentinel satellite constellation as well as contributing satellite missions[25]. Using this satellite infrastructure defined image products are set up and provided to the Copernicus services. The most important image products are derived from high resolution or very high resolution optical satellite sensors. To achieve seamless and cloud-free European image mosaics, (extensive) acquisition windows are defined around reference years. So far, the timely acquisition and delivery of the required satellite images is still a challenge at European level[26]. With the upcoming Sentinel satellites shorter image acquisitions and deliveries are expected.

The following core datasets are available for the HRL and local component production (Table 7):

- Optical HR Pan Europe coverage (HR_IMAGE_2015)
- European optical MR1 composites (MR_IMAGE_2015)
- European HR2 multitemporal coverages (EUR_HR2_MULTITEMP)
- Optical VHR multispectral and panchromatic coverage over Europe (VHR_IMAGE_2015)
- VHR1-2 Urban Atlas 2012

[23] According to the current CSDA Portfolio https://copernicusdata.esa.int/documents/12833/14545/DAP_Release_Phase_2
[24] e.g. for the Data warehouse requirements 2014-2020 see http://copernicus.eu/sites/default/files/library/Data_Warehouse_V2_0.pdf
[25] http://www.copernicus.eu/main/satellites
[26] Status of image delivery reference year 2015 see: https://copernicusdata.esa.int/documents/12833/14553/CORE_DWH2_Web_Status)

Table 8: Copernicus image products (reference year 2015) relevant for land monitoring

Copernicus component	ESA image title	Spatial resolution	Reference year	Delivery
All HRL, CLC	HR_IMAGE_2015	10-20m	2015 but Spot-5 data are available only in 2014. Systematic tasking took place in 2014 for Resourcesat-2 over Europe within the extended windows, and will continue in 2015 within the extended windows.	2014 archive will be delivered starting in Q2 2015. Data acquired in 2015 will be available after the end of the acquisition campaign.
All HRL	EUR_HR2_MULTITEMP	22m	Monthly acquisition windows starting on April 1st and ending in October 31st 2015	All data will be delivered within 2015 (monthly delivery of the whole of Europe)
All HRL	MR_IMAGE_2015	60m	8 monthly coverages from March to October 2014.	Within 2015
Urban atlas	VHR1-2 Urban Atlas 2012	0.4-1.2m	Feb 2011- Oct 2013, to be completed by acquisitions in 2015	Within 2015
Riparian zone	VHR_IMAGE_2015	0.4-4m	2015 +/-1 year	Delivery will be made at the end of each acquisition window, per large regions and no later than 90 days after acceptance, assuming progressive production approval by EEA.

5.1.2 Copernicus production plans

In December 2014, the European Commission signed a delegation agreement with EEA for the implementation of the Pan-European and Local components. The Technical Annex[27] of this agreement describes the update plans for the Copernicus land components for the period 2014-2020. In continuation of the GMES initial operation phase (GIO) 2011-2013, all HRLs will be updated in a 3-yearly cycle. The first HRL update should thus be with the reference year 2015, the second update being in 2018. All HRL production is based on the ESA image datasets provided via the Data Warehouse mechanism. The CLC production is based on a six-yearly cycle, with the next update planned in 2018. The Urban Atlas component has been produced in 2006 and 2012, but changed to a 5-yearly update cycle, i.e. an update is proposed for 2017[27] but has not been finally decided yet.

Table 9: Availability and update plans for the Copernicus land products (Status 22.09.2015)

Pan-European Component	Available Products	Next planned update
CLC	1990, 2000, and 2006, 2012 (under production)	2018
HRL FTY, TCD, PWB, NGR	2012 (partly under production, party available)	2015
HRL IMD	2006, 2009, 2012 (under production)	2015
Local components		
Riparian LC/LU, GLE	2012 (under production)	2018
Urban Atlas	2009, 2012 (under production)	2017 (proposed)

Regarding the HRL production timeline it is important to note that the production of the 2012 HRLs was in many cases the first operational run (except IMD). This means that with gaining experience on workflows and products further updates are likely to speed up. The 2012 production took place in a transition phase regarding the satellite image availability. All 2012 HRLs depended on ESA contributing satellite missions, where the timely delivery of Pan-European coverages still provided challenges. This meant that extensive image gap filling took place until late 2013, causing to HRL

27 http://cop.fdc.fr/sites/default/files/library/SIGNED_EU_EEA_ANNEX-I_Description%20of%20tasks_Ares%282014%294012930.pdf Last accessed 22.09.2015

production to start late 2013 or even in 2014. Therefore, in combination with the complex production workflow (see Figure 12) the final dissemination of the 2012 HRLs is expected not before late 2015.
For the 2015 HRL production workflow simplifications are planned. The aim is to reduce the production time to 1 year between the moment of image availability at the end of each acquisition season and the information service availability. The HRLs 2015 still rely on contributing satellite missions, due to the availability of Sentinel-2 not before late 2015. This 1-year production phase is likely not to be reached in 2015 but envisaged for 2018.

Based on the ESA image planning and the current Copernicus production plan a timeline view can be made to highlight interdependencies between the programmes. **This timeline is based on several assumptions and uncertainties** such as:

- The production of the HRL 2015 and 2018 will speed up due to optimized workflows and image availability
- With the upcoming Sentinel-2 data availability, Pan-European HR coverage will be achieved in shorter time
- HRL 2018 and CLC 2018 are running in parallel
- The Urban Atlas update cycle is five years with the next update in 2017

Looking at the timeline (Figure 13), **it is favourable that both LUCAS and Copernicus operate mostly in a 3-yearl update cycle with the next update planned in 2018**. However, two aspects can be noticed:

- The proposed shift of **Urban Atlas to a 5-yearly update cycle prevents the use of (adequately timed) LUCAS data**
- to optimally feed the LUCAS data into the Copernicus production phases the timely LUCAS processing and publication phase in Q2 2016 and 2018 is a strength

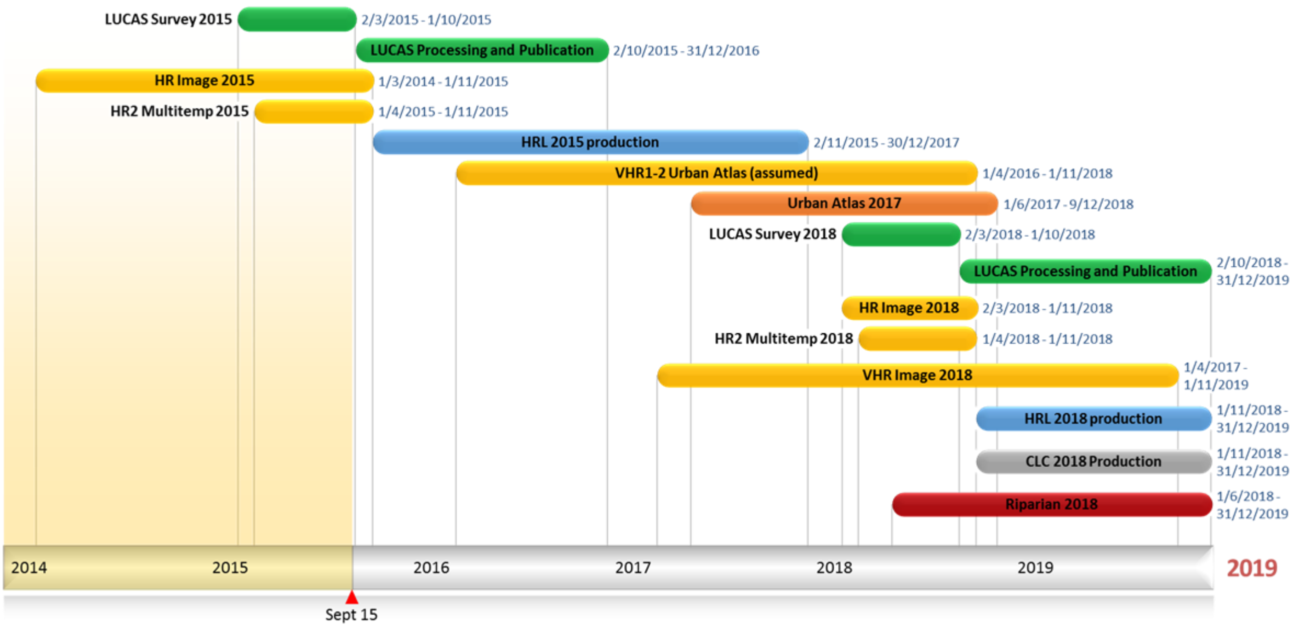


Figure 13: Indicative production timeline LUCAS – Copernicus 2014-2020

5.2 Cartography, scale and application

The resolution and scale of geo-data is important for its analysis. Keeping in mind, It is important to note that there are several fundamental differences in the purpose, background and nature of the different Copernicus and LUCAS product (Table 10).

Table 10: Resolution and scale of LUCAS and Copernicus products

	Geometric Resolution / Equivalent Scale	MMU	Nature of the data	Coverage
LUCAS	Not applica-ble	Not applicable	In situ measurement of a survey point. Sample size is a 1.5m or 20m radius around the point.	Sampling grid
CLC	1:100.000	25ha, 5ha change	Photo-interpretation of HR satel-lite images (>10m pixel size)	Wall-to-wall coverage
UA	1:10.000	0.25ha	Photo-interpretation of VHR satellite images (<2.5m pixel size)	Urban areas
Riparian	1:10.000	0.5ha	Semi-automatic analysis of VHR	Riparian zone

	Geometric Resolution / Equivalent Scale	MMU	Nature of the data	Coverage
Zone			satellite images (<=2.5m pixel size)	
HRL	Not applica-ble	None (20x20m pixel for inter-mediate prod-ucts 100x100m final products, 1ha (0.5ha FTY)	Combination of automatic proc-essing and interactive rule based classification of VHR-HR satellite images	Wall-to-wall coverage

Figure 14: The "dimensions" of a LUCAS sampling point

Positively speaking the **HRL minimum width (as defined by the 20x20m pixel size) is in line with the LUCAS extended window applicable for inhomogeneous classes (**Figure 14). Due to the comparatively large CLC MMU (25ha) there are specific generalisation rules in CLC to "ingest" small patches of varying land cover types within a larger surrounding. While in LUCAS the observation size is only a 1.5m radius or in certain inhomogeneous areas 20m, this **LUCAS information cannot simply be extrapolated to the CLC 25ha polygon**. The definition of woodland and forest for example is defined in LUCAS by the canopy cover observed at 20m around the LUCAS point. The CLC Class 231 (pasture) allows 10-30% canopy cover, which can occur through small local concentration of trees with a much higher (LUCAS) canopy cover rate or through more or less evenly dispersed trees. A LUCAS point within such a small local concentration would have a much higher canopy cover (40-100%) due to the smaller observation size, while a LUCAS point located next in an open space might have 0% coverage of trees. In the case of the LUCAS woodland/forest example **additional LUCAS metadata assists in the interpretation, such as the recorded “area size”** recorded in LUCAS (<0.5 ha, 0.5-1ha, 1-10 ha, >10ha). This metadata information could be used to filter LUCAS points applicable for the specific Copernicus data. **Landscape photos can also assist in the interpretation** of the point surrounding, albeit not in an automatic approach.

Different positional accuracies apply due to the nature of the input data sources and the geometric resolution of the product. This could lead to a mismatch of LUCAS point information and Copernicus data layer as illustrated in an example (Figure 15) from our spatial analysis of the IMD product and LUCAS described in chapter 5.4.

Figure 15: Different scale and geometric resolutions lead to a potential mismatch of LUCAS sample point (yellow, LC=Axx) and IMD product (red pixels indicating %imperviousness)

5.3 Thematic analysis

The most recent **LUCAS 2015 and Copernicus nomenclatures were analysed in-depth using correspondence matrices**. The **detailed matrices** relating each Copernicus product to the LUCAS nomenclature produced correspondence tables can be found in Annex 3 – Correspondence tables linking LUCAS to the Copernicus classes. The analysis was based on the latest available specification guidelines and documents (Table 11).

Table 11: Specification used for the thematic analysis

	Specification document and version
LUCAS	Technical reference document C1 – Instructions for Surveyors, 2015[28] Technical reference document C3 classification (Land cover & Land use), 2015[29]
CLC	CORINE land cover technical guide – Addendum 2000Technical addendum[30]
UA	Urban Atlas 2012 Mapping Guide (provided by EEA, not publicly available yet)
Riparian Zone	CS-3_17 NOMENCLATURE GUIDELINE, Issue 2.0 of 19/06/2015 (provided by EEA, not publicly available yet)
HRL	GIO land (GMES/Copernicus initial operations land) High Resolution Layers (HRLs) – summary of product specifications. Version 11 of 2015-08-03[31]

Set against the LUCAS 2015 LC/LU class combinations as reference, all Copernicus classes were cross-related. Using this approach, **three correspondence values** could be attached to each corresponding LUCAS–Copernicus class pair (Table 12), where:

- 0 = the LUCAS LC/LU class combination is not relevant for the Copernicus class
- 1 = the LUCAS LC/LU class combination is fully contained within the specific Copernicus class
- 2 = the LUCAS LC/LU class combination is partially contained within the specific Copernicus class

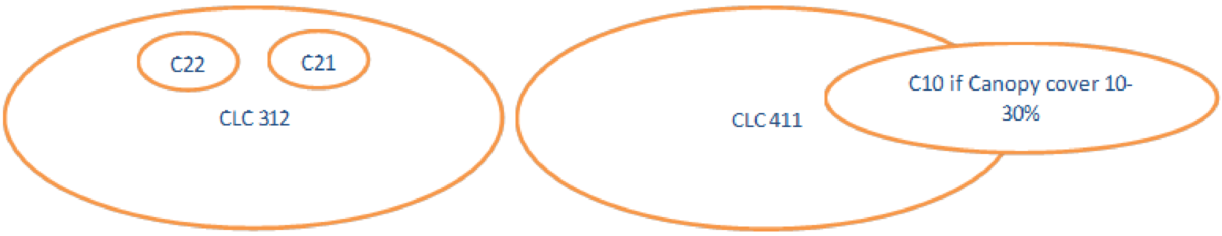
[28] http://ec.europa.eu/eurostat/documents/205002/6786255/LUCAS2015-C1-Instructions-20150227.pdf/bbc63453-568f-44fc-a149-8ef6b04626d7 date accessed: 30.10.2015

[29] http://ec.europa.eu/eurostat/documents/205002/6786255/LUCAS2015-C3-Classification-20150227.pdf/969ca853-e325-48b3-9d59-7e86023b2b27 date accessed: 30.10.2015

[30] http://www.eea.europa.eu/publications/tech40add date accessed: 30.10.2015

[31] https://cws-download.eea.europa.eu/pan-european/hrl/HRL_Summary_for_publication_v11.pdf date accessed: 30.10.2015

The correspondence value of "1" means, that this particular LUCAS LC/LU combination is more detailed or equal to the related Copernicus class. For example, the CLC class 312 fully includes (contains) the LUCAS LC classes C10, C21, C22, C23 etc.



Value "1"   Value "2"

If class characteristics differ (e.g. tree density levels, maturity definitions, altitude restrictions ….) or are missing from one of the related class pairs, the value "2" should be used. This means the LUCAS LC class is only partially included in the Copernicus class, like for example in the case of the CLC class 411, where the canopy cover is different for the LUCAS C10 class:

Table 12: Setup of the correspondence tables

	Copernicus class			
	CLC 111		**CLC 112**	
LUCAS LC class	Value	LUCAS LU code	Value	LUCAS LU code
A11	[0,1,2]	[Uxxx]	[0,1,2]	[Uxxx]
A12	…	…	…	…
…	…	…	…	…

In a **first summary approach**, it was checked whether all LUCAS classes are relevant for Copernicus and the number of correspondence values recorded for each LUCAS LC class.

In a next analysis step all problematic class pairs (indicated by the value of "2") were further discussed to see if the correspondence difficulties are due to

- a limited knowledge on the application of the LUCAS data and its data model and content or
- differences or ambiguities in the LC/LU definitions.

Based on this analysis, recommendations on the use of LUCAS or adaptations to the LUCAS data nomenclature were made to improve the future usability of LUCAS within Copernicus.

5.4 Spatial analyses of example datasets

To test the correspondence between LUCAS data and Copernicus layers (all from the reference year 2012) in an empiric approach, three different examples data sets of Copernicus have been spatially analysed with LUCAS 2012 data. These were:

- HRL Imperviousness with LUCAS data from Germany (full coverage)
- HRL Forest with LUCAS data from France (full coverage)
- Riparian zones with LUCAS data from selected riparian zones in Bulgaria and Romania

Goal of these analyses was to:

- determine how the LUCAS sampling covers the Copernicus layers and
- find the degree congruence of the already existing LUCAS and Copernicus LC/LU codes.

Although the technical approach between the HRL raster layers and the riparian vector layers was slightly different, the basic mechanisms were the same: The **LUCAS 2012 point data was super-imposed on the Copernicus dataset**. Using different **spatial analysis** tools, the value of the Copernicus data layer was stored in a database in combination with the LUCAS point information at the same position. The result is a database including the LUCAS data (e.g. Position/LC/LU information etc.) and the Copernicus value for each position corresponding LUCAS point position. It was then further analyzed which LUCAS points can be used thematically based on the developed correspondence tables, i.e. how many LUCAS LC/LU points can be used to compare with a HLR area or a Riparian zone feature and vice versa.

The comparison of LUCAS and Copernicus data was done in a very strict way, i.e. only the exact point location was used and only the LUCAS LC/LU information was retrieved. The results thus represent the minimal congruence between the two datasets. This analysis could be further enhanced and extended to (but was considered out of the scope of this study):

- Adjust spatial analysis to LU/LC combinations
- Use of additional LUCAS metadata (i.e. area size)

  Buffer LUCAS points for certain meters to decrease the change of points being “misplaced” by just a couple of meters, due to different geographic resolution of the compared data sets

6 Results

6.1 Thematic analysis

The first **summary analysis showed that generally there is already a good match**, whereas the more complex Copernicus products CLC and UA had more correspondence difficulties, expressed in the code “2” (ANNEX 4). This is partly due to the problem of the applied minimum mapping units in CLC (25ha) and UA (0,25ha) as described before, partly because of the missing strict distinction between land cover and land use within the CLC and UA nomenclature. **All correspondence values of “2” were further analysed and discussed in depth**. This analysis showed that the results generally need to be separated into

- **Recommendation to use LUCAS in Copernicus,** if the LUCAS data already provides the required information, but specific metadata aspects, or LC/LU combinations have to be applied
- **Recommendations to improve and adapt LUCAS** in its classes, metadata etc.

All recommendations where categorized to recommendation types (A,B,C…), to group similar or identical recommendations. The detailed class specific recommendations are presented in the following chapters in tabular form. All LUCAS class recommendations across the Copernicus land monitoring products can be found in ANNEX 5.

6.1.1 CLC

To use the LUCAS data in any CLC validation process there are several **recommendations on the use of specific LUCAS classes** (Table 13).

Table 13: Class specific recommendation to use LUCAS in CLC

LUCAS LC Code	LU Code	CLC Class	Recommendations to use LUCAS in Copernicus	Type
A21, A22	U370 U410	112	Limited usage of LUCAS LU=410, due to CLC 25ha MMU and generalisation rules.	D
G11, G12, G21, G22, G30	U313	123	Limited usage due to CLC 25ha MMU and generalisation rules.	C H
Bxx	-	211, 212	Irrigation/drainage is also observed at the LUCAS points and categorised e.g. irrigation by channel/pond etc. This can be used to retrieve irrigation information.	A
F40	U111/U112	211	Considering the combinations of LC1/LC2 with LU1/LU2 it is possible to evaluate whether a point falls on 'arable' land or not. The specific combination LC1 F40/ U111 is always arable land in LUCAS (C3 p.60).	A
G11, G21	U111	211, 213	Irrigation/drainage is also observed at the LUCAS points and categorised e.g. irrigation by channel/pond etc. This can be used to retrieve irrigation informa-	A

LUCAS LC Code	LU Code	CLC Class	Recommendations to use LUCAS in Copernicus	Type
			tion.	
F40	U111	212	Considering the combinations of LC1/LC2 with LU1/LU2 it is possible to evaluate whether a point falls on 'arable' land or not. The specific combination LC1 F40/ U111 is always arable land in LUCAS (C3 p.60).	A
F40	U111	213	Landscape photos taken at the LUCAS point can assist interpretation. If rice is detected LUCAS LC class will be B17	G
B82	U111	221	The percentage of land cover (>50%) can be used.	A
F40	U111	221	Vineyards B82 are assed within the extended observation window (20m radius), thus only if there is a spot with a 20m radius of bare soil in a vineyard, will the pure code F40/ U111 not reveal that the point is in a vineyard. This is probably a very rare case. In all other cases of smaller spots of bare soil the LUCAS point will be coded B82/U111.	F
G11	U111	221, 222	Landscape photos taken at the LUCAS point can assist interpretation.	G
B37	U111	222	add B37b to B70 and B80 (exclusive B83) for comparison with CLC 222	B
B7x	U111	222	The percentage of land cover (>50%) can be used..	A
F40	U111	222	Fruit trees/shrubs (B7x) are assessed within the extended observation window (20m radius), thus ONLY if there is a spot with a 20m radius of bare soil, will the F40/ U111 not reveal that the point is within fruit trees. This is probably a very rare case. In cases of smaller spot of bare soil the LUCAS point will be coded B7x/U111.	A
F40	U111	223	Olive trees (B81) are assessed within the extended observation window (20m radius), thus ONLY if there is a spot with a 20m radius of bare soil, will the F40/ U111 not reveal that the point is within an olive plantation. This is probably a very rare case. In cases of smaller spot of bare soil the LUCAS point will be coded B81/U111 anyway.	A
C10, C2x, C3x	U111	231	The percentage of land cover can be used. If there is a woodland (>10% canopy cover) with grassland and LU U111 below it will be coded as LC2/LU2	A
D10	U111 U112	231	The percentage of land cover can be used. If there is a woodland (>10% canopy cover) with grassland and LU U111 below it will be coded as LC2/LU2	A F
Various LUCAS LC code	Various LUCAS LU Codes	241, 242, 243	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	G H
B1x (except B17), B2x, B3x, B4x (except B44), B5x, C10, C2x, C3x, E10, E20, E30, F40	U111, U112	244	Can be detected by considering LUCAS specific LC1 and LC2 (with relevant U111). If there is a second LU in a forest, e.g. grazing animals there are two LC and two LU given.	A

LUCAS LC Code	LU Code	CLC Class	Recommendations to use LUCAS in Copernicus	Type
C10, C2x, C3x	U120, U420	311, 313, 321	The percentage of land cover can be used. A Cxx Class is in LUCAS if there are >10% tree canopy.	A
D10, D20	U420	321	The percentage of land cover can be used. Usable if LUCAS percentage of land coverage = 10-25%.	A
D10, D20, F30	U420	333	The percentage of land cover can be used.	A
F40	U120 U40x	334	There is a specific remark (LUCAS field form C2 field No 37)indicating 'burnt area'	A
C10, C2x, C3x	U420	411	The percentage of land cover can be used.	A
D10, D20	U420	412	The percentage of land cover can be used.	A

To improve the future use of LUCAS there are several **recommendations to adapt and enhance the LUCAS nomenclature** to better address the CLC classes (Table 14).

Table 14: Class specific recommendation to adapt and improve LUCAS for CLC usage

CLC Class	Proposed adaptation to LUCAS	Type
111, 112	Add parameter for extended 20m window, such as %impervious in groups (e.g. by 10% intervals)	D F
123,124	Recommend to record LU2 in case of U317 and other LUs in case if point belongs to port area (U313), airport area (U314)….	B C
131, 422	Subdivision of U140 to distinguish peat extraction, salines (not equal to salt mining)....	B
141, 142	U361: Create separate LU class for leisure, e.g.: - U361 (new) Amenities + leisure - U362 (remains) Sport - U363 (new) culture & museum, …. => CLC142 = U361+U362 Additional parameter for CLC 141 needed if U36x "urban/non-urban context"	B
211	Exclude option G12/U111 from C3 LUCAS nomenclature.	B
311, 313, 32x, 411	Harmonize % of land coverage assessment to 10% intervals	F E
321, 322, 323, 324	Increase class details for shrubs. E.g. analogue to forest types. CLC 321 may contain dwarf pine up to 25%. CLC 322 includes temperate shrubby vegetation (e.g. heathland, alpine scrub, brown dunes…) excludes mattoral vegetation (maquis, garrique…). CLC 323 represents bushy sclerophyllous vegetation and includes mattoral vegetation (maquis and garrigue). CLC 324 makes a distinction between climax and transitional shrubland (turning ultimately into forest vegetation)	B
331	Add bare land types to Fxx: beach, dune, river banks.	B
333	Add Ex as LC2 even without second LU.	B
335	Harmonize glacier definitions.	B
521, 522	Apply new special remark in LUCAS (lagoon, estuary)	C

6.1.2 HRL

To use the LUCAS data in any HRL validation process there are several **recommendations on the use of specific LUCAS classes** (Table 15).

Table 15: Class specific recommendation to use LUCAS in HRL

LUCAS LC Code	LU Code	HRL Class	Recommendations to use LUCAS in Copernicus	Type
D10	U111, U112, U120, U36x, U420	1-100 tree cover density values (TCD)	In LUCAS D10 shrubs have to cover more than 10% and trees <10%. Land coverage percentage of trees is per definition between 5-10%. LC1 coverage percentage refers to shrubs. The width of feature attribute describes the geometry (< or > 20x20m). If the width of a feature is below 20x20m, it is not recommended to use the data for TCD validation.	A
C3x	U111, U120, U341, U350, U36x, U370, U420	3 mixed forest (FTY)	In LUCAS 2015 there is a specific % check in 5% steps. This INSPIRE results can be used to check the % of coniferous/broadleaved trees in 5% steps. This is relevant for the FTY with 50-75% coniferous/broadleaved in 20m product. The C3x class can be directly applied to the mixed forest type in the 100m product.	A
A13	-	1-100 imperviousness values (IMD)	If A13 is part of the HRL definition it can be used.	B
A21	any	1-100 imperviousness values (IMD)	LC2 can be used to see if an A21/A22 area is sealed. If LC2 is not given, the area can be considered as mainly sealed.	A
A22	any (other than U311)	1-100 imperviousness values (IMD)	LC2 can be used to see if an A21/A22 area is sealed. If LC2 is not given, the area can be considered as mainly sealed.	A
A30	U210 U311 U312 U318 U321	1-100 imperviousness values (IMD)	It is recommended not to use A30 for IMD validation, due to the very heterogeneous nature of this class.	B

To improve the future use of LUCAS there are several **recommendations to adapt and enhance the LUCAS nomenclature** to better address the following HRL classes (Table 16).

Table 16: Class specific recommendation to adapt and improve LUCAS for HRL usage

HRL Class	Proposed adaptation to LUCAS	Type
TCD	Split B75 into two classes (B75 a-x Other fruit trees / B75x-k Other berries) in order not to mix trees and shrubs in this class.	B
FAD	For FAD product additional parameter needed if point in "urban/non-urban context".	C
IMD	Add parameter for extended 20m window, such as %impervious in groups (e.g. by 10% intervals)	D

6.1.3 Local Components: UA and Riparian Zone

To use the LUCAS data in any Local Component validation process there are several **recommendations on the use of specific LUCAS classes (**Table 17**,** Table 18**)**.

Table 17: Class specific recommendation to use LUCAS in Riparian Zone

LUCAS LC Code	LU Code	Riparian Class	Recommendations to use LUCAS in Copernicus	Type
C10, CxxC	U120 U420	3.1.1.1	It is recommended to use the LUCAS LC forest types for the comparison with different Riparian Zone forest types. LUCAS forest types are given when the woodland is >0.5 ha, the width of feature >20 m and height of maturity >5 m. C10C represents Floodplain Forest, which definition mainly overlaps with the description of 3.1.1.1	A
Cxx4, Cxx5, Cxx6, Cxx7, Cxx8, Cxx9, CxxE	U120 U420	3.1.1.1	Only use LUCAS forest types within the spatial boundaries (Riparian Zone) as defined by the Copernicus layer.	A
Cxx1, Cxx2, Cxx3, CxxA, CxxE	U120 U420	3.2.1.1	Only use LUCAS forest types within the spatial boundaries (Riparian Zone) as defined by the Copernicus layer.	A
Cxx	U111	4.1.1.1, 4.2.1.1, 4.2.1.2	Only LUCAS Cxx points with TCD>30% can be used.	A E F
E10/E20	U111	4.1.1.2, 4.2.2.1, 4.2.2.3	Temporary grassland are excluded from Exx. LUCAS Exx contains less than 10% (E10) or 5% (E20) tree/shrub coverage. In contrast for HRL <30% tree coverage is allowed.	A F
Dxx/Exx	U4x0	6.2.2.2	There is a remark field (no 37) in LUCAS indicating 'burnt areas'.	A

Table 18: Class specific recommendation to use LUCAS in UA

LUCAS LC Code	LU Code	UA class	Recommendations to use LUCAS in Copernicus	Type
Various LUCAS LC code	Various LUCAS LU Codes	11210, 11220, 11230, 12340	It is not recommended not to use these LUCAS classes, because it is not part of the UA class definition and only relevant due to the UA generalisation MMU of 0.25ha.	H

To improve the future use of LUCAS there are several **recommendations to adapt and enhance the LUCAS nomenclature** to better address the following UA and Riparian Zone LC classes (Table 19, Table 20):

Table 19: Class specific recommendation to adapt and improve LUCAS for UA usage

UA Class	Proposed adaptation to LUCAS	Type
11100	Add parameter for extended 20m window, such as %impervious in groups (e.g. by 10% intervals)	D
12300	Recommend to record LU2 in case of U317 and other LUs in case if point belongs to port area (U313), airport area (U314)…	B

Table 20: Class specific recommendation to adapt and improve LUCAS for Riparian Zone usage

Riparian Class	Proposed adaptation to LUCAS	Type
4.1.1.2, 4.2.2.1, 4.2.2.3	Add grassland types to Exx, such as dry, wet, alpine. A distinction is made between managed and semi/natural/natural grass-land (all with/without tress <>30%). In relation to semi-natural grasslands there is a division between dry, mesic and alpine grasslands, according to EUNIS habitat types (E1-6, B1.19).	B
5.1.1.1, 5.1.1.2, 5.2.1.1	Increase class details for shrubs. E.g. analogue to forest types. Here differentiation between a) Heathlands and Moorlands (related to EUNIS F1, F3, F4, F8,F9) and b) Other scrub land (EUNIS F2) and c) Sclerophyllous vegetation (EUNIS F5,F6,F7) is needed	B
6.2.1.1, 6.2.1.2, 6.2.1.3	Add bare land types to Fxx. Here differentiation needed beach, dune and river banks.	B

6.2 Spatial analysis

The first spatial analysis superimposed the LUCAS points with the HLR raster cells or riparian vector features. The results showed at there was a large number of points available for subsequent analysis, i.e. a high potential of LUCAS points to validate Copernicus layers (Table 21). It was then selected which LUCAS points can be used thematically based on the developed correspondence tables, i.e. how many LUCAS LC/LU points can be used to compare with a HLR area or a Riparian zone feature and vice versa. These analysis steps are presented in the following chapter per layer.

Table 21: Summary of usable LUCAS points for Copernicus validation (based on exemplary spatial analysis)

Copernicus Layer	LUCAS 2012 from	Total Number of LUCAS points	Points within Copernicus layer (value > 0 and <254)	Definition for LUCAS to fit in Copernicus Layer	Points
HRL Imperviousness	Germany	24.943	1.946	LC1 = 'Axx'	1.829
HRL Forest	France	38.338	10.481	LC1 = B7x/ B81/B82/B83/Cxx/D10	12.997
Riparian zones	Bulgaria Romania	6.642 14.279	1.561	Variable depending on riparian landcover clas-ses	X

6.2.1 IMD Germany

The **LUCAS data overlaps the IMD layer** (where it has a cell value of greater than zero and smaller than 254) **at 1.946 points in Germany** (Table 10, Figure 16). Furthermore, in the total LUCAS 2012 sample there are 1.829 points coded as "LC1 = Axx". These 1.829 "Axx"- Class points partially superimpose the HLR Layer at a value 1-100 and partially at a value of 0 (see Table 23). These can potentially be used for Copernicus validation exercises.

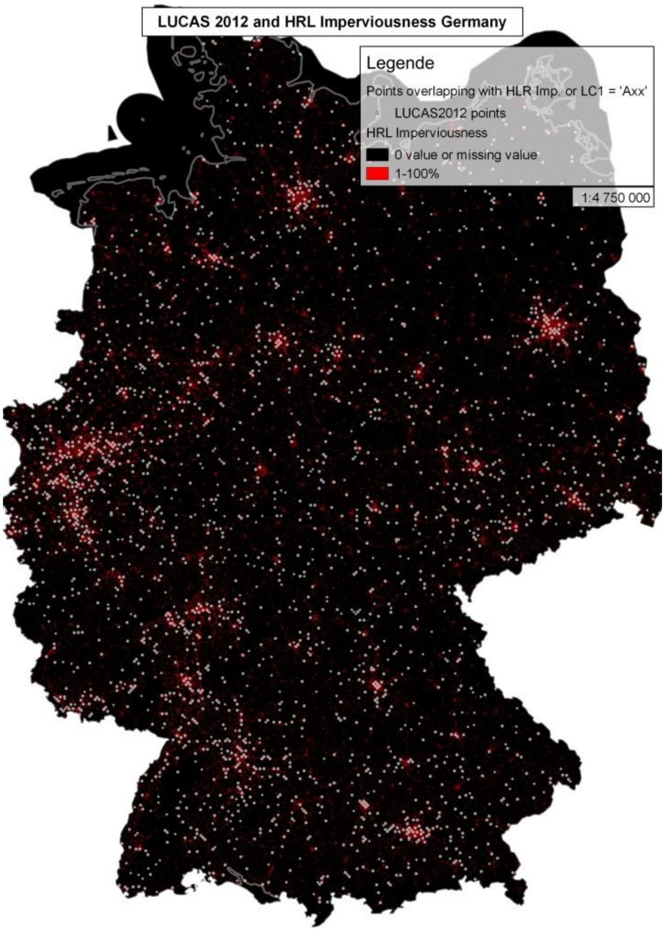


Figure 16: LUCAS 2012 data superimposed on IMD for Germany

In a next step, the LUCAS points were classified into five categories according to the following rules:

- Cat 1: [LUCAS LC1 ≠ ‘Axx’] and [Imperviousness value = 1-100%]
- Cat 2: [LUCAS LC1 = ‘Axx’] and [Imperviousness value = 0]
- Cat 3: [LUCAS LC1 ≠ ‘NULL’] and [Imperviousness value = 254 (no data)]
- Cat 4: [LUCAS LC1 = ‘Axx’] and [Imperviousness value = 1-100%]
- Cat 5: [LUCAS LC1 ≠ ‘Axx’] and [Imperviousness value = 0]

The category 1 and 2 points show where the LUCAS data (using only LC) does not match with the IMD information. Points falling in category 3 are superimposing the HLR Layer at a location where there is no IMD value available for analysis (IMD value = 254, e.g. due to cloud coverage in the base satellite images). LUCAS points categorized 4 and 5 show a good match to the IMD layer, in that there is some confirmed degree of imperviousness at the point (category 4) or there is no sealing recorded at the point in both data sets (category 5). Summing up all category 4 and 5 points, **a very high degree of conformity could be observed between LUCAS and the IMD layer**, confirming the findings of the thematic analysis (Table 22). An example of the spatial distribution of the different category points was illustrated for the Ruhr area in North-West Germany (Figure 17).

Table 22: Conformity of IMD and LUCAS 2012 data for Germany expressed in the number of categorized sample points

Cat 1	Cat 2	Cat 3	Cat 4	Cat 5	Total	% of congruent points (Cat. 4 and 5)
758	624	482	1.188	21.891	24.943	92,5%

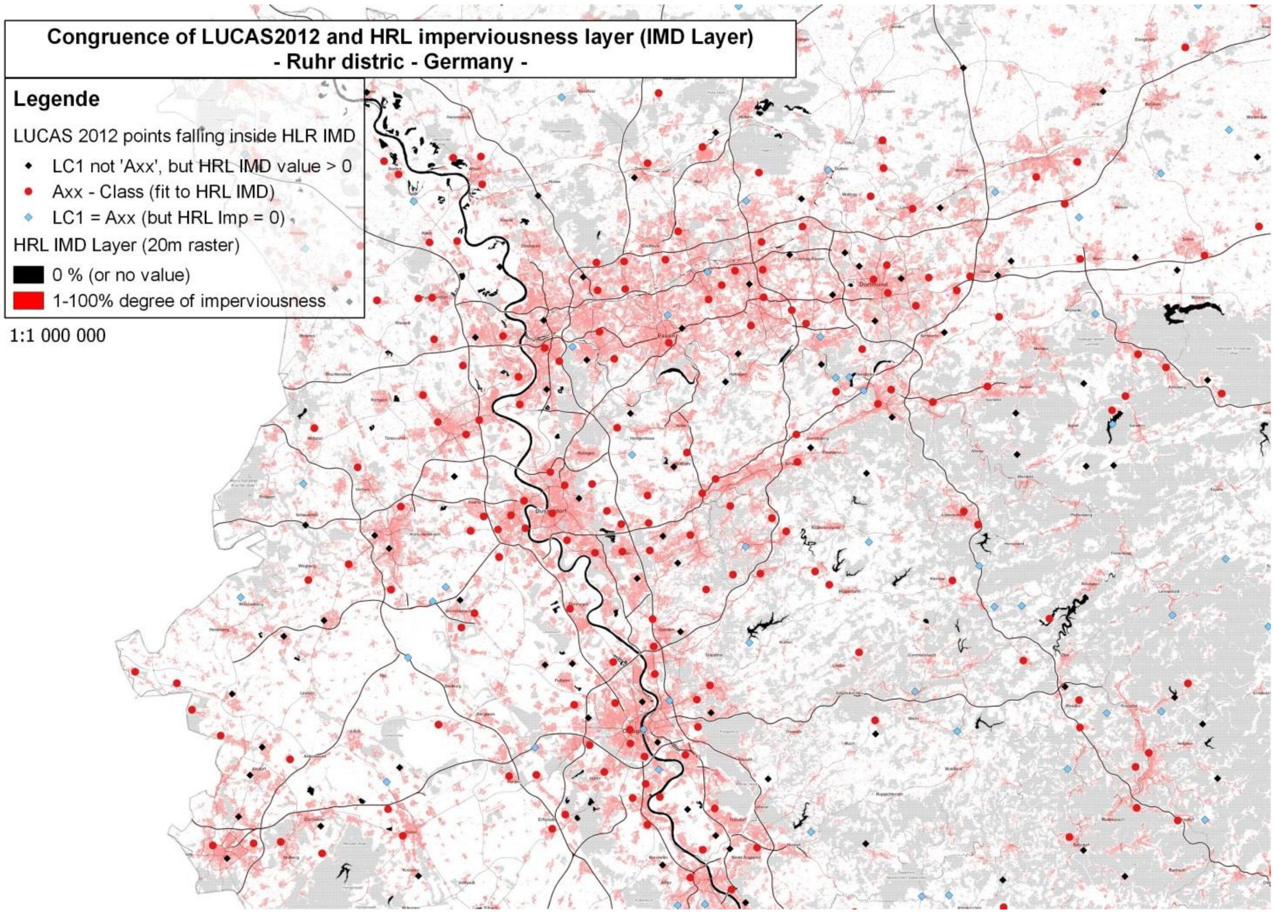


Figure 17: Regional example of congruence of IMD and LUCAS 2012 data (Ruhr area, Germany)

A more detailed data analysis summarized the LUCAS Axx classes separately and their fit with the IMD layer (Table 23). The first column shows the different LUCAS classes and the second column gives the total amount of points for the respective LUCAS class. The following columns split the total amount of LUCAS points per class in three categories, depending on the IMD value. Within the table are also the five conformity categories, as mentioned above, marked. The green points (Category 4 and 5) are again in agreement with the IMD values, while the red ones (Category 1 and 2) do not match and for the grey ones there is no IMD data available.

Table 23: Class level analysis of the conformity of LUCAS and IMD for Germany

LUCAS Class	Sum of LUCAS points	Points on imp 1-100		% of LUCAS points on Imp 1-100	Point on imp = 254 (HLR: no data)		Points on imp = 0	
A11	538	**419**	Category 4	77.88%	3	Category 3	116	Category 2
A12	73	**68**		93.15%	1		4	
A13	4	**3**		75.00%	0		1	
A21	454	**346**		76.21%	2		106	

LUCAS Class	Sum of LUCAS points	Points on imp 1-100		% of LUCAS points on Imp 1-100	Point on imp = 254 (HLR: no data)		Points on imp = 0	
A22	760	**352**		46.32%	11		397	
Bxx	8315	110	Category 1	1.32%	213		**7992**	Category 5
Cxx	8053	185		2.30%	145		**7723**	
Dxx	263	31		11.79%	5		**227**	
Exx	5697	398		6.99%	90		**5209**	
Fxx	203	21		10.34%	2		**180**	
Gxx	455	12		2.64%	8		**435**	
Hxx	128	1		0.78%	2		**125**	
Total	**24943**	**1946**			**482**		**22515**	

6.2.2 TCD France

The HLR Forest (TCD) of France was analyzed in the same way. There are 10.481 LUCAS points that superimpose the HLR Layer at a value of TCD > 0 and < 254 (no data). Furthermore in the total LUCAS 2012 sample there are 12.997 LUCAS points coded LC = B7x/B81/B82/B83/Cxx/D10,thus that would fit into the TCD layer according to the correspondence matrix.

Again the LUCAS points were separated in five distinct conformity categories and:

- Cat 1: [LUCAS LC1 ≠ ‘B7x/B81/B82/B83/Cxx/D10’] and [TCD value = 1-100]
- Cat 2: [LUCAS LC1 = ‘B7x/B81/B82/B83/Cxx/D10’] and [TCD value = 0]
- Cat 3: At a LUCAS point the [TCD value = 254 (no data)]
- Cat 4: [LUCAS LC1 = ‘B7x/B81/B82/B83/Cxx/D10’] and [TCD value = 1-100%]
- Cat 5: [LUCAS LC1 ≠ ‘B7x/B81/B82/B83/Cxx/D10’] and [TCD value = 0]

Table 24: Conformity of TCD and LUCAS 2012 data for France expressed in the number of categorized sample points

Cat 1	Cat 2	Cat 3	Cat 4	Cat 5	Total	% of congruent points (Cat. 4 and 5)
1.580	4.086	39	8.901	23.732	38.338	85,1 %

This time, the **overall degree of conformity was not as high as for the IMD layer** (Table 24). The spatial distribution of the TCD layer and the LUCAS points (only the “B7x/B81/B82/B83/Cxx/D10” classes) was illustrated for France (Figure 18). It appears that the category 2 points (orange) are linked in their local distribution to the category 4 points (green) and to the TCD distribution. Therefore further spatial analysis (e.g. considering spatial buffers) or including LC2 codes might further improve the degree of conformity.

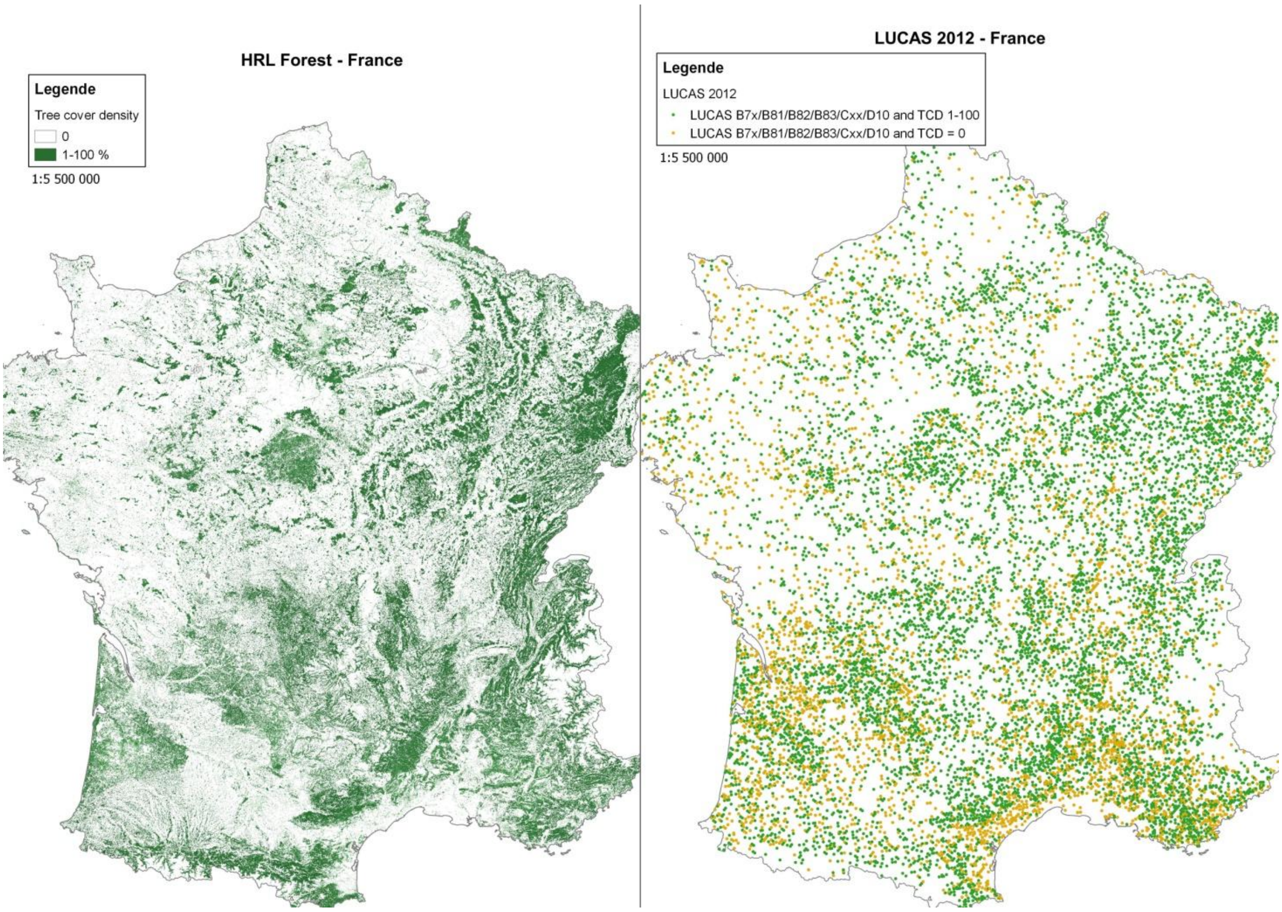


Figure 18: Spatial distribution of the TCD layer and LUCAS conformity points for France

The more detailed class analysis showed the matching pattern for the TCD relevant LUCAS classes (Table 25). However, it also shows where there are problematic areas to further looked at in the use of LUCAS data, or vice versa in the validation of the Copernicus layer. It is for example explainable that the D20 class “Shrubland without tree cover” is likely to be confused with TCD values >0, if detected in an automated satellite image analysis. Yet, it is surprising to see a relatively large percentage of Gxx (Water areas) to be found in the TCD area. These aspects could be addresses further, but are out of the scope of this study.

Table 25: Class level analysis of the conformity of LUCAS and TCD for France

LUCAS Class	Sum of LUCAS points	Point on TCD 1-100		% points TCD 1-100	Points on missing value TCD >= 254	Points on TCD = 0	
Axx	2170	274	Category 1	12.63%	2	1894	Category 5
B1x-5x	11052	148		1.34%	7	10897	
B7x/81/82/83	946	52	Category 4	5.50%	1	893	Category 3
B84	17	0	Category 1	0.00%	0	17	Category 5
C10	8081	5913	Category 4	73.17%	6	2162	Category 2
C21	505	462		91.49%	1	42	
C22	1018	758		74.46%	0	260	
C23	64	48		75.00%	0	16	
C31	692	630		91.04%	0	62	
C32	786	645		82.06%	1	140	
C33	148	122		82.43%	0	26	
D10	757	271		35.80%	1	485	
D20	512	113	Category 1	22.07%	1	398	Category 5
E10	1745	253		14.50%	2	1490	
E20	8150	536		6.58%	7	7607	
E30	845	131		15.50%	1	713	
Fxx	249	32		12.85%	1	216	
Gxx	512	79		15.43%	8	425	
Hxx	89	14		15.73%	0	75	
Total sum	**38338**		**10481**		**39**	**27818**	

6.2.3 Riparian zones in Bulgaria and Romania

As a last example, **an extract from the Riparian Zone layer was compared with the LUCAS 2012 data** over parts of Bulgaria and Romania. In contrast to the comparison with the IMD and TCD layers, which simply represents one type of information value scaled from 1-100%, the riparian layer has its own land cover nomenclature. Thus to compare the LUCAS2012 data with the riparian layer more 'translation' was needed. This comparison relied on the matrix connecting the riparian layer with the LUCAS data. Due to the geographical constraints of the riparian layer only LUCAS points falling into the riparian zone were analyzed. These points were checked if they fit the proposed combination of LC/LU and riparian zone class out of the correspondence matrix. In total there are 1.561 LUCAS points within the riparian layer. **Of these points 976 (i.e. a conformity of 63%) correspond in their LC/LU combination to the proposed riparian classes** (Figure 19, Table 26).

The class level correspondence was also assessed for the Riparian Zone LC product (Table 26). The first column lists the different riparian classes. The following columns show how many unique LUCAS LC/LU combinations, the total sum of LUCAS points and the sum of LUCAS points that fit to the riparian class according to the correspondence matrix. For example: Within the riparian class 1111 – 'Continuous urban fabric (in-situ based or IM.D. >80-100%)' there are 3 unique LUCAS LC/LU combinations, represented in a total of 6 LUCAS points. Out of those, 5 points match the correspondence matrix LC/LU values attached to the riparian class 1111.

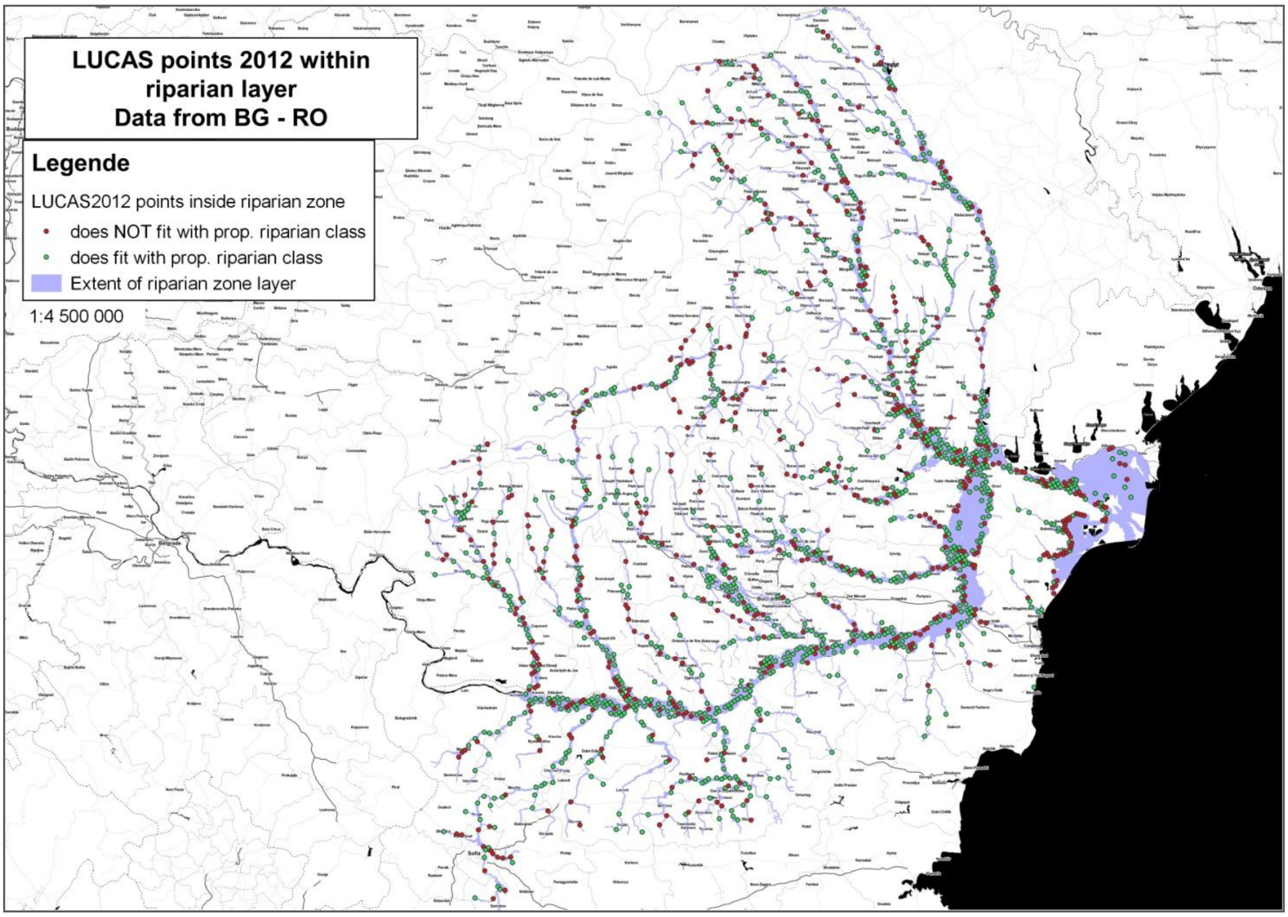


Figure 19: Correspondence of LUCAS LC/LU combinations to Riparian zone LC

The **translation matrix from riparian to LUCAS and vice versa matches quite well**, although **it can be improved for certain classes.** The 'percentage of points fit' highlight class specific issues, which could be used to further improve the correspondence between riparian zone nomenclature and LUCAS. This can be achieved by fine-tuning the riparian classes and the LC/LU combinations in detail and by using more LUCAS parameters than LC and LU (see chapter 6); with a focus on the classes with low '%point fit' and high number of points.

Table 26: Class level analysis of the conformity of LUCAS and the Riparian zone example in Bulgaria and Romania

Riparian Zone Classes	Unique LUCAS LC/LU combinations	Sum of LUCAS points	Number of points fit	% of points fit
1111	3	6	5	83%
1112	20	33	15	45%
1113	14	15	2	13%
1121	17	32	10	31%
1211	5	7	3	43%
1212	2	2	0	0%
1311	3	3	2	67%
1321	1	1	0	0%
2111	45	447	344	77%
2131	26	204	156	76%
2141	10	13	10	77%
2321	18	37	28	76%
2331	16	26	15	58%
3000	1	7	7	100%
3100	2	2	1	50%
3111	26	141	100	71%
3131	12	44	33	75%
3211	5	8	0	0%
3231	5	12	10	83%
3311	1	1	0	0%
3331	7	20	5	25%
3411	27	88	18	20%
4000	4	4	1	25%
4111	2	2	1	50%
4112	7	14	8	57%
4221	19	120	87	73%
4222	12	43	19	44%
5000	1	1	0	0%
6111	7	9	1	11%
6213	10	19	8	42%
6221	1	1	0	0%
7100	1	2	2	100%
7111	7	22	12	55%
8111	4	14	11	79%
8211	2	34	4	12%
8221	3	4	3	75%
9000	3	3	2	67%
9100	4	5	1	20%
9111	11	35	8	23%
9112	6	8	3	38%
9113	6	6	1	17%
9121	6	11	4	36%
9210	4	8	6	75%
9211	6	44	29	66%
9214	3	3	1	33%
Total:		**1561**	**976**	**63%**

7 Conclusions

This technical report analysed in-depth the use and application of LUCAS in view of the Copernicus land monitoring services. The analysis was conducted on several levels:

- **Review of the current use and application of LUCAS** in previous or ongoing Copernicus land monitoring services through an online survey and expert consultation.
- **Review of the current Copernicus implementation status**, production methods and data models applied in the Copernicus land monitoring services.
- **Review on a temporal scale** to highlight production phases for harmonization.
- **A thematic analysis** to identify recommendations on the future use of LUCAS and propose adaptations to the current LUCAS data model.
- **A spatial empirical analysis** to support the thematic analysis and confirm the already high conformity of LUCAS and Copernicus data.

In summary there is a list of recommendation to improve the usability of LUCAS across the different scales (Table 27).

Table 27: Summary of recommendations

Scale	Type	Recommendation
Thematic	A	Consider entire LUCAS data model in order to apply correlation with non-LUCAS classes, see Annex 2 and chapter 2.5
	B	Adapt/extent LUCAS LC/LU classes, e.g. → Exx**x**, Dxx**x**, Fx**xx** (analogous to Cxx**x** forest types) → U140 to U141/U142/U142 → Expand LC/LU combinations
	C	Add additional variable (by analogy with “burnt area”) for peat bogs, salines, harbours, airports
	D	Add additional sealing parameter (in 10% steps)
	E	Harmonise class thresholds (different land cover percentages apply in nomenclatures)
	F	Extent INSPIRE pure land cover classes to all existing LC classes in extended LUCAS window
	G	Consider application of LUCAS landscape photos

Scale	Type	Recommendation
	H	Consider Copernicus generalisation rules (e.g. CLC 25ha MMU)
Temporal		The proposed shift of Urban Atlas to a 5-yearly update cycle prevents the use of (adequately timed) LUCAS data. A six-yearly update cycle would allow and optimized use of LUCAS.
Spatial		The spatial analysis confirmed largely the good conformity of LUCAS - Copernicus products. It is recommended to extend this spatial analysis beyond the scope of this technical report. This shall include all Copernicus products to consolidate and improve the correspondence matrices and assess statistical validations aspects.

Further explanations are given to describe these recommendations:

Type A: During the analysis it could be noted, that most reported mismatches could be solved or “translated” through the application of the full LUCAS data model (e.g. all point observation and metadata recorded according to the LUCAS C1[32] and C2 document[33]). There seems a lack of easily applied and understandable information regarding the use of LUCAS in Copernicus related validation activities. This is backed up by the findings of the online survey and the feedback from the Copernicus domain experts.

Type B: Increasing the level of details for some LUCAS LC class would assist a better application with Copernicus, such as e.g. a split of LU U140 with additionally U141 = peat bogs and U142 = salines. Further the grassland, shrubland and bare land classes might be more elaborated in order to better address Copernicus layers on one hand side but also the prevailing impacts of land cover changes in natural environments.

---

32 Technical reference document C1 Instructions for Surveyors http://ec.europa.eu/eurostat/documents/205002/6786255/LUCAS2015-C2-FieldForm%26GD-Template-20150227.pdf/ea8a176c-317a-4e0d-b354-9c1b10df046e last accessed 05.10.2015

33 Technical reference document C2 Field Form and Ground Document (template) http://ec.europa.eu/eurostat/documents/205002/6786255/LUCAS2015-C1-Instructions-20150227.pdf/bbc63453-568f-44fc-a149-8ef6b04626d7 last accessed 05.10.2015

Type C-D: Some additional metadata recording such as the degree of sealing in the extended LUCAS window for all points may help to better match with the imperviousness layer.

Type E-F: Different land cover percentage thresholds for the discrimination of LC classes complicate the assignment of LUCAS classes to Copernicus classes. Helpful could be an adaption of the INSPIRE pure land cover classes (recorded in LUCAS in 2015 for the first time), which should cover the whole extended window and record the coverage of all existing LC in e.g. 10% steps (according to the main LUCAS classes A, B, C, D ,E ,F, G, H).

Type G: Special attention should be paid on the usage of the LUCAS landscape photos, especially the understanding of point data (= always connected to the point coordinate) and the position of the photos taken (= can be different from LUCAS coordinate and therefore can show other landscape features).

Type H: Copernicus generalisation rules (especially different MMU of products) lead to different view on LUCAS data and their usability. This must be acknowledged in data analysis. It would be advisable to provide guidelines on the use of LUCAS with respect to scaling issues.

Spatial and scale aspects: The spatial analysis in this study was only performed on selected regions and for selected Copernicus products (IMD, TCD, Riparian LC). Further empirical investigations could consolidate and improve the thematic matching of LC/LU codes to the Copernicus class. The recent semantic work by the EAGLE[34] group to match Copernicus and LUCAS nomenclatures[35], could benefit from these spatial study results and help to fine tune their bar encoding approach.

Based on these recommendations the following actions are proposed to further improve the usability and uptake of LUCAS in Copernicus.

---

[34] EAGLE (EIONET Action Group on Land Monitoring in Europe) web page: http://sia.eionet.europa.eu/EAGLE (current page, last visit September 2015), http://land.copernicus.eu/eagle (new page, planned Q4 2015)

[35] Under Contract SC55998 based on the restricted procedure No EEA/MDI/14/012 following a call for expression of interest EEA/SES/13/005-CEI

ACTION1:

LUCAS user manuals should be prepared to highlight and explain the use of LUCAS micro data (including the relevant metadata) for Copernicus related validation tasks.

ACTION2:

The LUCAS nomenclature and data model should be revised and adapted to include the identified LC/LU and metadata issues identified in this report.

ACTION3:

The empirical spatial analysis of LUCAS and Copernicus products should be extended to consolidate the thematic matching of LUCAS LC/LU codes with Copernicus classes.

ACTION4:

The results from this study should be provided to the EAGLE working group to support their work on the semantic translation of Land cover / Land use nomenclatures in Europe.

8 References

Arnold, S., Kosztra, B., Banko, G., Smith, G., Hazeu, G., Bock, M., Valcarcel Sanz, N. 2013: The EAGLE concept – A vision of a future European Land Monitoring Framework. In: R. Lasaponara, L. Masini and M. Biscione (Eds.). Towards Horizon 2020: Earth Observation and Social Perspectives. 33th EARSeL Symposium Proceedings, pp. 551-568. Matera: EARSeL and CNR. http://www.earsel.org/symposia/2013-symposium-Matera/pdf_proceedings/EARSeL-Symposium-2013_10_2%20_Arnold.pdf

Bossard, M., J. Feranec, Otahel J. 2000: CORINE land cover technical guide – Addendum 2000. EEA Technical report No 40. URL: http://sia.eionet.europa.eu/CLC2000/classes

Büttner, G., Maucha, G. 2006: The thematic accuracy of Corine Land Cover 2000. Assessment using LUCAS (land use / cover area frame statistical survey). EEA Technical Report No 7/2006. ISSN 1725-2237. http://www.eea.europa.eu/publications/technical_report_2006_7

Büttner, G., Kosztra, B. 2007: CLC2006 Technical Guidelines, EEA, Technical Report 17/2007. http://www.eea.europa.eu/publications/technical_report_2007_17

Büttner G., Kosztra B., Maucha G. 2013: Final report on Task 3.1 Operational working procedures. In: Commonalities, differences and gaps in national and sub-national land monitoring systems. EU FP7 HELM Deliverable 4.1 Part 3 Operational working procedures, pp. 6-39–. URL:http://www.fp7helm.eu/fileadmin/site/fp7helm/HELM_3_1_Commonalities_and_Differences.pdf (last visited 12.08.2015)

European Commission Eurostat, 2010: Peer Review LUCAS. – 11 p., LUCAS reference Metadata in Euro SDMX, Annex 3, Eurostat. Online, Available from: http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/en/lan_esms.htm (Accessed: 12.7.2013).

GALLEGO, F.J. (2006) Review of the main remote sensing methods for crop area estimates. In: *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences Vol. XXXVI, No. 8/W48.* ISPRS WG VIII/10 Workshop 2006. Remote sensing support to crop yield forecast and area estimates. pp. 65-70. [Online] Available from http://mars.jrc.ec.europa.eu/Bulletins-Publications/Remote-Sensing-Support-to-Crop-Yield-Forecast-and-Area-Estimates (29.09.2015).

Gallego, F.J., Delincé, J., 2010. The European land use and cover area-frame statistical survey, in: Benedetti, R., Bee, M., Espa, G., Piersimoni, F. (Eds.), Agricultural Survey Methods. John Wiley & Sons, New York, pp. 151–168.

Haub, C., Quilitz, K., Lindemann, D. & Leskinen, E., 2013: Surveying European landscape dynamics, Journal for Photogrammetry, Remote Sensing and Geoinformation Science, 2013(5), pp. 473–482.

Jacques, P., Gallego, F.J., 2006. The LUCAS 2006 project–A new methodology, in: Compilation of ISPRS WG VIII/10 Workshop 2006, Remote Sensing Support to Crop Yield Forecast and Area Esimates. Stresa, Italy, JRC - ISPRA – MIPSC/AGRIFISH unit.

Kosztra, B., Arnold, S. 2013: Proposal for enhancement of CLC nomenclature guidelines. ETC/SIA deliverable EEA subvention 2013 WA1 Task 261_1_1: Applying EAGLE concept to CLC guidelines enhancement. EEA internal report. URL: http://forum.eionet.europa.eu/nrc_land_covers/library/gio-land/corine-land-cover-clc/technical-guidelines/enhanced-clc-nomenclature-guidelines

Palmieri, A., Dominici, P., Kasanko, M. & Martino, L., 2011: Diversified landscape structure in the EU Member States. – Eurostat – Statistics in focus, theme 21/2011: 12 p., ISSN 1977-0316, KS-SF-11-021-EN-N, European Union.

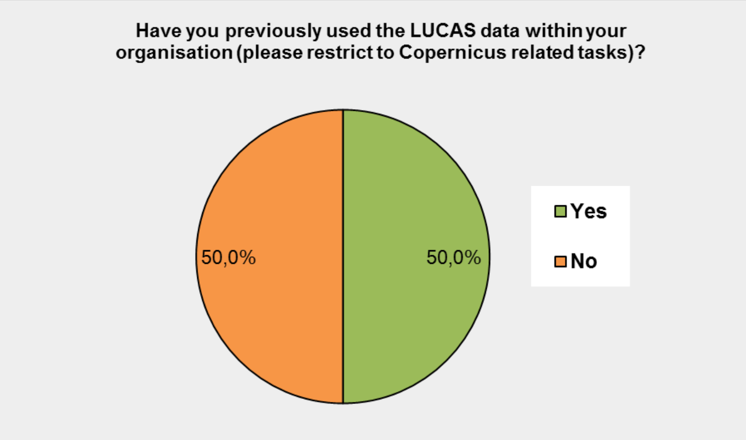
Martino, L., Palmieri, A., Gallego, F.J., 2009. Use of auxiliary information in the sampling strategy of a European area frame agro-environmental survey, in: Proceedings of the ITACOSM09 - First Italian Conference on Survey Methodology. Siena 10-12 June 2009. URL: http://ec.europa.eu/eurostat/documents/205002/769457/LUCAS2009_S2-Sampling_20090000.pdf/cb9197df-d621-4436-bd0b-19f8da6b40bc (2015-08-11)

Kleeschulte S., Kosztra B., Arnold S., Banko G. 2014: Final Report Restricted procedure No EEA/MDI/14/009 ("Contract 1": Task 1.1 Explanatory Documentation of EAGLE concept, Task 1.2 Fine-tuning of Matrix/Model and Task 1.3 UML Data Model) following a call for expression of interest EEA/SES/13/005-CEI 'Assistance to the EEA in the production of the new CORINE Land Cover (CLC) inventory, including the support to the harmonisation of national monitoring for integration at pan-European level'.

Tóth, G., Jones, A., Montanarella, L. (eds.) 2013. LUCAS Topsoil Survey. Methodology, data and results. JRC Technical Reports. Luxembourg. Publications Office of the European Union, EUR26102 – Scientific and Technical Research series – ISSN 1831-9424 (online); ISBN 978-92-79-32542-7; doi: 10.2788/97922"

Annex 1 Online survey response

Have you previously used the LUCAS data within your organisation (please restrict to Copernicus related tasks)?



Why did you not use LUCAS previously?		
Answer Options	**Response Percent**	**Response Count**
Lack of knowledge about LUCAS	36,4%	4
Data access inadequate	36,4%	4
Data inadequate	36,4%	4
Other reasons	45,5%	5
Please specify in more detail:		7
	answered question	**11**
	skipped question	**9**

Name	Organisation	Please specify in more detail:
Chantal Melser	Statistics Netherlands	We produce national data of land use that are of better quality on each regional level.
Dr. Tom Klingl	Federal Office For The Envi-ronment FOEN	Because Switzerland uses data of the Swiss land cover and land use statistics (see http://www.bfs.admin.ch/bfs/portal/de/index/themen/02/03/blank/data/geodaten.html)
Kevin Lydon	EPA Ireland	The attribution does not give a CLC code and with the large number of LUCAS LU & LC codes it is hard to readily convert into the CORINE classification schema. Lack of stratification makes means there is not enough points to reliably use LUCAS for assessing accuracy of some CORINE classes. It is however useful for manual checking of areas within which there is a LUCAS point.
Kolbeinn Arnason	National Land Survey of Iceland	No LUCAS system in Iceland

Jiri Kvapil	CENIA, Czech Environmental Information Agency	Today the LUCAS is not needed any more. There is very detailed orthoimagery (25 cm/px) updated every two years in the CZ. LUCAS was a very good product in 1990's and 2000's but currently it has come to an end of life product phase due to newer technologies available. Products like Google Street View or similar imagery services provided by local mapping companies can replace LUCAS. In CZ we also have very detailed topographic maps and other in-situ data (crop plans, forest inventory, etc.). For us LUCAS doesn't bring anything new, any added value that we would like to use it.
Michał Klusek	Head Office of Geodesy and Cartography	In regard to the tasks currently performed by the Head Office of Geodesy and Cartography, it is not necessary to use LUCAS data.
Antonio Perdigão	DGADR-MAM	We do not have a deep inside knowledge about LUCAS, and their potentialities, lack of Information from EEA.

Which of the three LUCAS components did you use and how?

Answer Options	Stratification tasks	Training classifier	Verification tasks	Statistical validation	Other tasks	Response Count
Micro data: land cover, land use and environmental parameters associated to the single surveyed points?	2	1	5	4	2	8
LUCAS photos: Point and landscape photos in the four cardinal directions	1	1	2	3	3	7
LUCAS statistics: Statistical tables with aggregated results by land cover, land use at geographical level	1	0	0	1	1	2
Other tasks (please specify)						5
					answered question	**8**
					skipped question	**12**

Name	Organisation	Other tasks (please specify)
Geoff Smith	Specto Natura Ltd.	Within the Geoland2 project compared LUCAS generic land cover results to those acquired by VHR imagery and attempted to determine LUCAS point data where they are currently in accessible.
Pekka Härmä	Finnish Environment Institute	Comparison of LUCAS and national data in order to study comparability and usability of Finnish national data for the information needs of EUROSTAT (EUROSTAT Grant study).
GIO land team	EEA	EEA is project managing the implementation of GIO/Copernicus land services (local component, pan European Component and in-situ coordination). The actual technical work is usually done by service industry or ETC.
Geir-H Strand	NFLI	Illustrations in papers and presentation (LUCAS Photo). Analysis of outfield land resources, in particular outfield pasture. The Norwegian version of Lucas include a wall-to-wall land cover map of the entire PSU (based on LUCAS 2003 methodology). These data are used for a multitude of statistical analysis as well as for training and verification purposes
Mário Caetano	Direção-Geral do Território (DGT)	(1) LUCAS has been mainly used as ancillary data on the production of land cover land use (LCLU) maps based on visual interpretation of aerial photography and satellite images, e.g. CORINE

		Land Cover and National LCLU Map (COS). (2) DGT also collaborated with the National Statistical Office to compare LCLU statistics derived from LUCAS and national LCLU maps. (3) We are now starting an exercise to use LUCAs sampling points to identify the polygons of the national LCLU map that are not correctly classified.

Please describe in detail the technical workflow applied to use the data (e.g. including preprocessing steps, level of LC/LU detail used etc.):

Name	Organisation	Response
Geoff Smith	Specto Natura Ltd.	Basic land cover (water, forest, grassland, agriculture, urban etc.).
Pekka Härmä	Finnish Environment Institute	Cross tabulation of LUCAS micro data and national GIS data, comparison of information content in micro data level
GIO land team	EEA	Refer to EEA Technical report http://www.eea.europa.eu/publications/technical_report_2006_7[36] Lucas data (photos and micro data) is used in some way by all GIO land HRL production service providers. For some more information, see the 2014 survey results.[37]
Geir-H Strand	NFLI	We can provide reports with descriptions[38]
Feigenspan	Umweltbundesamt	DLR used LUCAS data as additional input dataset during CLC2006
Mário Caetano	Direção-Geral do Território (DGT)	Regarding point (1) above, the LUCAS sampling points are displayed on the screen of aerial photography and satellite images for helping the identification of LCLU class. The interpreter checks LUCAS points whenever necessary.[39]

Can you recommend contacts on technical level to interview for further details:	
Answer Options	**Response Count**
	5
answered question	**5**
skipped question	**15**

Name	Organisation	Response
Geoff Smith	Specto Natura Ltd.	Geoff Smith.

[36] Additional remark by Author: The thematic accuracy was only assessed once for CLC 2000 using LUCAS

[37] Additional remark by Author: This refers to the EEA survey in 2014 (see chapter 3.1)

[38] Provided upon request http://www.tandfonline.com/doi/abs/10.1080/00291951.2012.760001

[39] Additional remark by Author: “point (1)” = the LUCAS LU/LC micro data information

GIO land team	European Environment Agency	Barbara Kosztra (FOMI)
Geir-H Strand	NFLI	ghs@skogoglandskap.no
Feigenspan	Umweltbundesamt	manfred.keil@dlr.de
Mário Caetano	Direção-Geral do Território (DGT)	Filipe Marcelino - fmarcelino@dgterritorio.pt

What are the strengths of the three LUCAS components from your perspective?	
Answer Options	**Response Count**
	8
answered question	**8**
skipped question	**12**

Name	Organisation	Response
Geoff Smith	Specto Natura Ltd.	Repeat measurements of the same location over long time periods.
Pekka Härmä	Finnish Environment Institute	Open availability of micro data measured/estimated in the field Timeliness (every 3. years)
GIO land team	European Environment Agency	provides data at temporal intervals that match Copernicus activities Regular updated information that contains some useful LU/LC information and photographs that can be helpful in difficult classification questions.
Geir-H Strand	NFLI	a) The systematic sampling approach providing unbiased statistical estimates with known statistical properties. b) The fact that all data are obtained in the field (and not by remote sensing) (in Norway, we also visit the locations in high mountain areas) c) Norway adds the 4th component as the wall-to-wall map of the PSU. This is the most useful part of the data as we see it
Javier Gallego	JRC-EC	Homogeneous survey across EU
Feigenspan	Umweltbundesamt	Sampling Point for whole Europe Photos
Mário Caetano	Direção-Geral do Território (DGT)	Data collected on the ground. Periodicity.

Where are the limitations of the three LUCAS components from your perspective?

Answer Options	Response Count
	7
answered question	**7**
skipped question	**13**

Name	Organisation	Response
Geoff Smith	Specto Natura Ltd.	The LUCAS data is too focused on the point and the transect.
Pekka Härmä	Finnish Environment Institute	Micro data may have potential for validation of Copernicus land services if information content (variables, classifications) of LUCAS will be matched with Copernicus data and amount of objective measurements will be added to the LUCAS survey. Information content of LUCAS is low within forest and seminatural surfaces.
GIO land team	European Environment Agency	so far, the incomplete coverage which was now achieved. missing the remaining EEA cooperating countries and EFTA countries, variable quality of the photographic documentation. Sampling design with a focus on agriculture, and less on non-agricultural landscape elements. Increased number of sampling points would be useful, in particular for less frequent classes.
Geir-H Strand	NFLI	a) The 2003-design with 18 km intervals is vulnerable to systematic variation between parallel fiords/valleys separated by mountains. b) Point data are too limited - wall-to-wall land cover map of the PSU is needed in addition c) Recent sampling design (stratified) is too complicated and becomes too expensive in mountain areas. 2003-design (18 km interval) is more appropriate, but may have to be "densified" in certain areas (18x9 or 9x9 km).
Javier Gallego	JRC-EC	Incomplete coverage Frequent fake changes between years
Mário Caetano	Direção-Geral do Território (DGT)	Sampling design. LCLU nomenclature.

Which future LUCAS modifications could improve your data needs?

Answer Options	Response Percent	Response Count
Sampling design	71,4%	5
Land cover / Land use classes	71,4%	5
Transect information	14,3%	1
Evironmental parameters observed at the point	0,0%	0
LUCAS photos	42,9%	3
Soil samples	0,0%	0
LUCAS statistics	14,3%	1

Others aspects	28,6%	2
Please specify in more detail:		7
	answered question	**7**
	skipped question	**13**

Name	Organisa-tion	Please specify in more detail:
Geoff Smith	Specto Natura Ltd.	It would be useful to have a broader view of the landscape which could be compared with EO-based products.
Pekka Härmä	Finnish Environment Institute	National and EU level land monitoring could benefit LUCAS micro data, if: -information content will be matched and improved especially in forest and semi-natural surfaces -visual estimates will be replaced with direct and more objective measurements in the field (for example forest characteris-tics) i.e. accuracy of LUCAS data will be improved
GIO land team	EEA	Extend to other countries. More frequent sampling points, also in LU classes currently underrepresented in LUCAS. Inclusion of more detailed LU/LC information that is harmonized with user needs and useful for a wide range of assessments (e.g. CLC, Copernicus land services etc.). Perhaps explore harmonisation with the EAGLE adopted nomenclature http://sia.eionet.europa.eu/EAGLE ? Improve and standardize quality and consistency of photo documentation.
Geir-H Strand	NFLI	Recent sampling design is too complicated. We prefer the 2003-design, with minor modification. Wall-to-wall land cover map of the entire PSU (1500 x 600 meters) is needed Land cover map require a more (but not too) detailed LC classification system Proper soil sampling probably too expensive, but wall-to-wall soil map of the PSU is a viable alternative
Javier Gallego	JRC-EC	More photo-interpretation can be used, in particular to cover areas difficult to reach land cover and use can be simplified more care needed to avoid different observation codes between years when there has been no change.
Mário Caetano	Direção-Geral do Território (DGT)	We are not sure if the LUCAs sampling design allows the identification of LCLU changes with enough accuracy, because of the low representative-ness of same class transitions. If one want to use LUCAS data to assess the accuracy of LCLU maps (e.g. CLC) the nomenclature of LUCAS has to be improved and match better the CLC classes. Furthermore, we are not sure if and how the statistical sampling design is adequate for accuracy assessment.

Which underlying mandates (e.g. directives, regulations) or thematic do-mains do you address with the Copernicus land monitoring services and products?

Answer Options	Response Count
	5
answered question	**5**

skipped question	**15**

Name	Organisation	Response
Geoff Smith	Specto Natura Ltd.	n/a
Pekka Härmä	Finnish Environment Institute	Land cover and land use change Water Framework directive Bird and habitats directive
GIO Land Team	EEA	Monitoring and documenting change in land characteristics for EEA39 countries, as part of the pan-European component of the Copernicus land services.
Geir-H Strand	NFLI	We assist EEA with their land monitoring activities. National LUCAS data have been used in CLC production and in the verification of HR Layers. Proper verification of HR Layers would probably not have been possible without national LUCAS data. Apart from that: None

Which future modifications of the Copernicus land monitoring services would enable a better use of LUCAS from your perspective?		
Answer Options	**Response Percent**	**Response Count**
Sampling design	66,7%	4
Land cover / Land use nomenclature	66,7%	4
Production steps	16,7%	1
Other	0,0%	0
Please specify in more detail:		7
	answered question	**6**
	skipped question	**14**

Name	Organisation	Please specify in more detail:
Geoff Smith	Specto Natura Ltd.	The use of a consistent data model, such as EAGLE, across the LUCAS and Copernicus products would aid in their integration. Synchronisation of surveys, image acquisitions and production time windows would allow wider combined use.
Pekka Härmä	Finnish Environment Institute	Enhanced comparability and combination of sample based (etc. LUCAS) and wall-2-wall (Copernicus EO based data) information would increase usability (quality, combined use) and benefits of both these data sources. Additionally efficiency of data production could be improved (avoid overlapping data collection, improved sampling design etc.)
GIO land team	European Environment	by covering all EEA countries they would provide a full area coverage of EEA activities under Copernicus

	Agency	The use, or lack of use of LUCAS data seems not to be currently limited by the setup and specifications of the land monitoring services. If and where LUCAS data provides a useful tool, it is being used. Of cause the use of LUCAS can be more explicitly made a requirement in product specifications, but in my view LUCAS is a tool that helps with our tasks, not the other way round, that our tasks need to be designed such that they enable LUCAS use.
Geir-H Strand	NFLI	We generally find the (national) LUCAS data much more useful than the Copernicus services for land monitoring purposes at the national and sub-national level, When Sentinel-2 data becomes available, there is a chance that (national) LUCAS data can be used for training and verification in order to establish useful national services. Current Copernicus land monitoring activities have little relevance at the national level. A possible modification is to link C services closer to sampling surveys with an established ground segment (e.g. LUCAS) in order to allow more sampling areas to be measured less frequently, but monitored by EO between ground campaigns.
Javier Gallego	JRC-EC	information on a larger area around the point
Mário Caetano	Direção-Geral do Território (DGT)	LCLU nomenclatures of LUCAS and Copernicus land products have to be matched. LUCAS should have more thematic detail in some LCLU classes. EAGLE model can be used to compare classes. Sampling design of LUCAs has to be evaluated to see if the LUCAS sampling points can be adequately used, in statistical terms, for assessing the thematic accuracy of Copernicus and national products. Two scales should be addressed: European and national. LUCAS should be designed so that it could be used to validate Copernicus products at national level by following a standard accuracy assessment defined at EEA level.

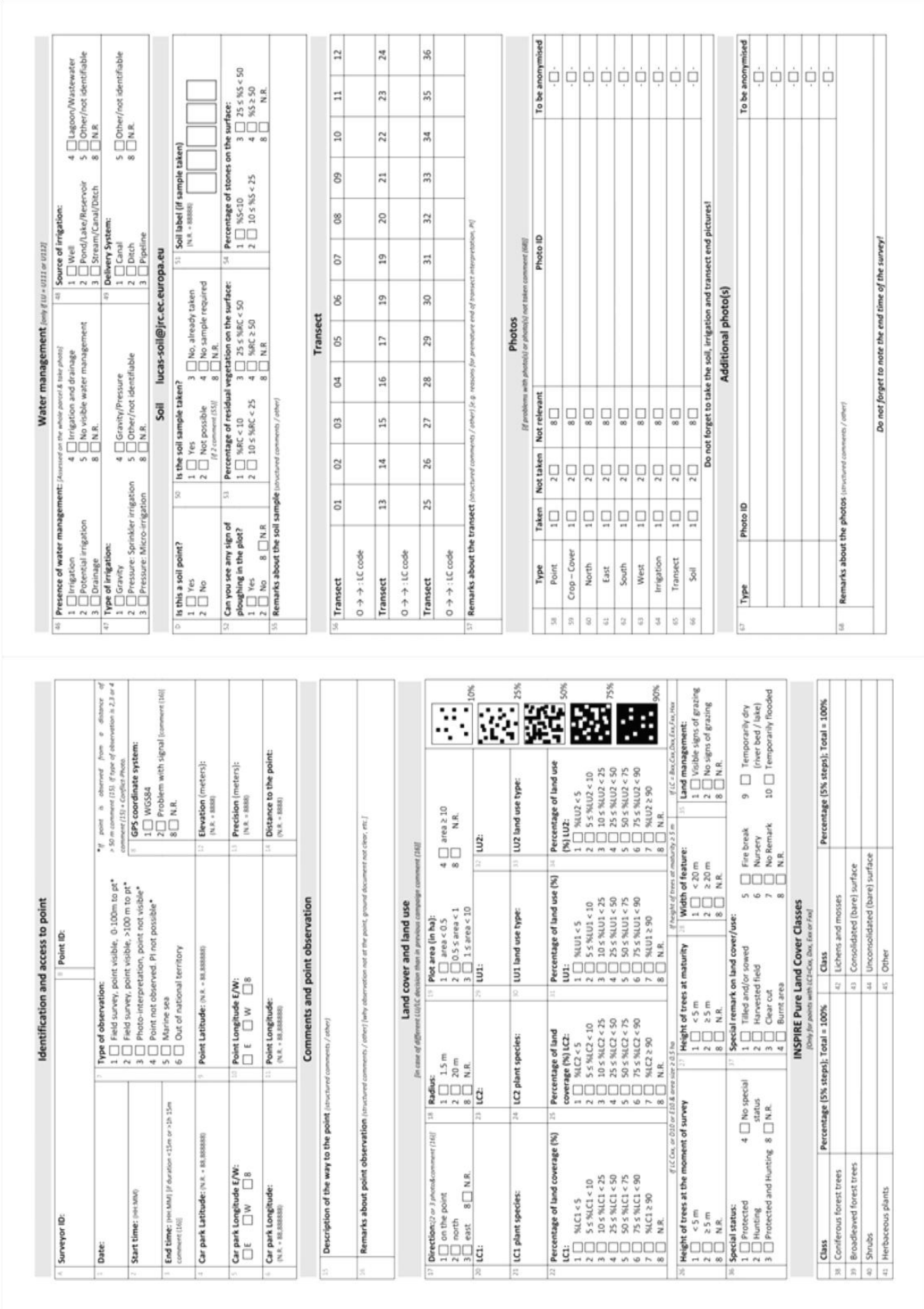
How would these modifications improve the quality and uptake of Copernicus from your perspective?	
Answer Options	**Response Count**
	5
answered question	**5**
skipped question	**15**

Name	Organisation	Response
Geoff Smith	Specto Natura Ltd.	Anything which improves the consistency of the product offering will promote user uptake.
Pekka Härmä	Finnish Environment Institute	Data quality could be better estimated, documented and improved and thus usability increased.
GIO land team	European Environment Agency	non-homogeneous coverage of EEA countries implies that he dataset is sometimes not used
Javier Gallego	JRC-EC	Better compatibility with Copernicus land layers (frequent resolution of 20-100 m)
Mário Caetano	Direção-Geral do Território	If LUCAS is used for assessing accuracy of Copernicus products at national scale by following a common and standard procedure, it might

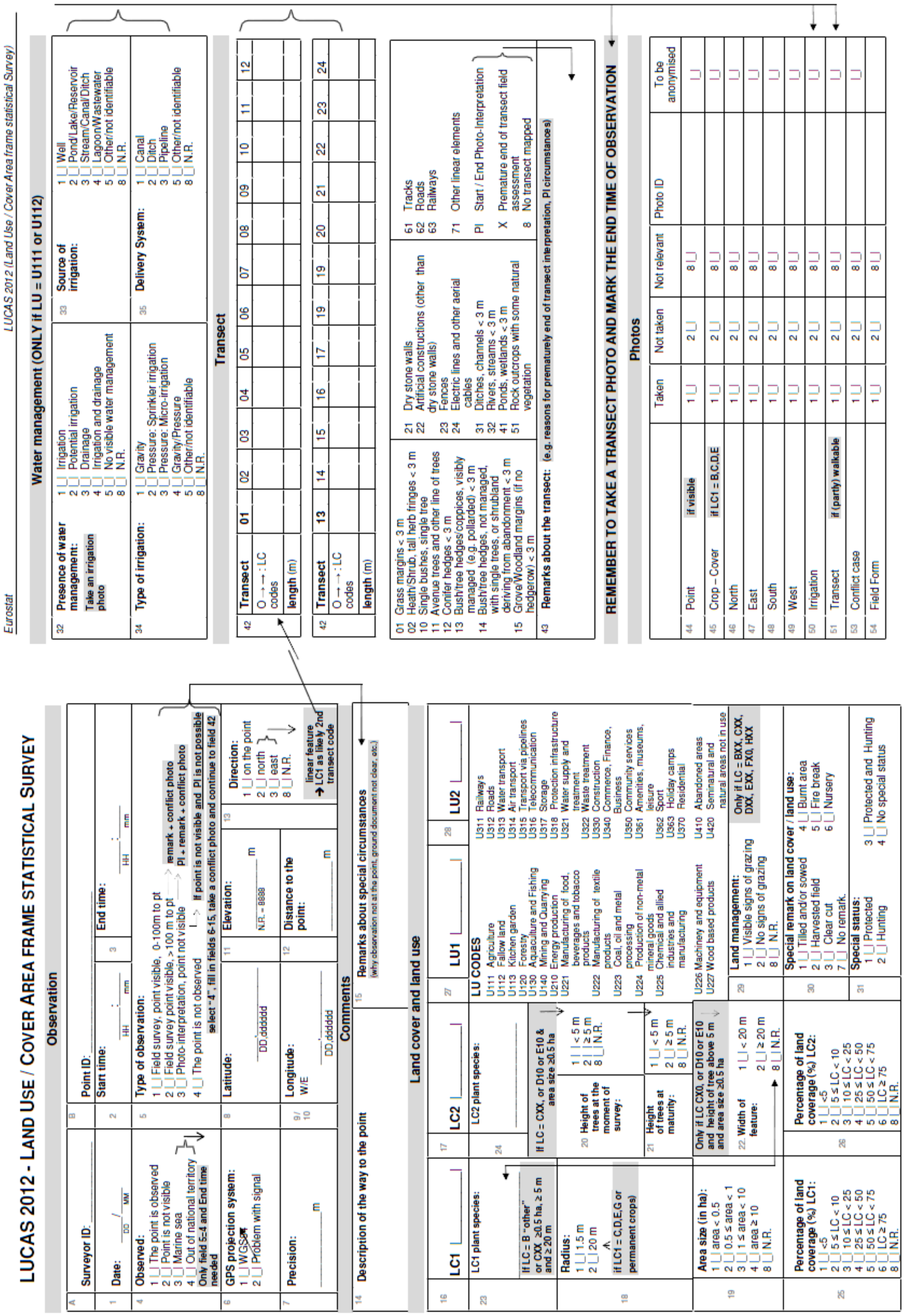
	(DGT)	improve the acceptance of these products by end users of some countries.

Annex 2 – LUCAS field forms

Annex 2.1 - LUCAS field form 2015



Annex 2.2 - LUCAS field form 2012



Eurostat — LUCAS 2012 (Land Use / Cover Area frame statistical Survey)

LUCAS 2012 - LAND USE / COVER AREA FRAME STATISTICAL SURVEY

Observation

A Surveyor ID: ____ | B Point ID: ____

1 Date: __/__ (DD MM) | 2 Start time: __:__ (HH mm) | 3 End time: __:__ (HH mm)

4 Observed:
1 The point is observed
2 Point is not visible
3 Marine sea
4 Out of national territory
Only field 5-4 and End time needed

5 Type of observation:
1 Field survey, point visible, 0-100m to pt
2 Field survey point visible, > 100 m to pt → remark + conflict photo
3 Photo-interpretation, point not visible → PI + remark + conflict photo
4 The point is not observed → If point is not visible and PI is not possible select "4", fill in fields 6-15, take a conflict photo and continue to field 42

6 GPS projection system:
1 WGS84
2 Problem with signal

7 Precision: ____ m

8 Latitude: DD,dddddd | 9/10 Longitude: W/E DD,dddddd

11 Elevation: ____ m (N.R. = 8888) | 12 Distance to the point: ____ m

13 Direction:
1 on the point
2 north
3 east
8 N.R.
linear feature → LC1 as likely 2nd transect code

Comments

14 Description of the way to the point
15 Remarks about special circumstances (why observation not at the point, ground document not clear, etc.)

Land cover and land use

16 LC1 | 17 LC2 | 27 LU1 | 28 LU2

23 LC1 plant species: | 24 LC2 plant species:

If LC = B "other" or CXX ≥0.5 ha, ≥ 5 m and ≥ 20 m

18 Radius:
1 1.5 m
2 20 m
if LC1 = C,D,E,G or permanent crops)

If LC = CXX, or D10 or E10 & area size ≥0.5 ha
20 Height of trees at the moment of survey: 1 < 5 m; 2 ≥ 5 m; 8 N.R.
21 Height of trees at maturity: 1 < 5 m; 2 ≥ 5 m; 8 N.R.

Only if LC CX0, or D10 or E10 and height of tree above 5 m and area size ≥0.5 ha
22 Width of feature: 1 < 20 m; 2 ≥ 20 m; 8 N.R.

19 Area size (in ha):
1 area < 0.5
2 0.5 ≤ area < 1
3 1 ≤ area < 10
4 area ≥ 10
8 N.R.

25 Percentage of land coverage (%) LC1:
1 <5
2 5 ≤ LC < 10
3 10 ≤ LC < 25
4 25 ≤ LC < 50
5 50 ≤ LC < 75
6 LC ≥ 75
8 N.R.

26 Percentage of land coverage (%) LC2:
1 <5
2 5 ≤ LC < 10
3 10 ≤ LC < 25
4 25 ≤ LC < 50
5 50 ≤ LC < 75
6 LC ≥ 75
8 N.R.

LU CODES
U111 Agriculture
U112 Fallow land
U113 Kitchen garden
U120 Forestry
U130 Aquaculture and Fishing
U140 Mining and Quarrying
U210 Energy production
U221 Manufacturing of food, beverages and tobacco products
U222 Manufacturing of textile products
U223 Coal, oil and metal processing
U224 Production of non-metal mineral goods
U225 Chemical and allied industries and manufacturing
U226 Machinery and equipment
U227 Wood based products
U311 Railways
U312 Roads
U313 Water transport
U314 Air transport
U315 Transport via pipelines
U316 Telecommunication
U317 Storage
U318 Protection infrastructure
U321 Water supply and treatment
U322 Waste treatment
U330 Construction
U340 Commerce, Finance, Business
U350 Community services
U361 Amenities, museums, leisure
U362 Sport
U363 Holiday camps
U370 Residential
U410 Abandoned areas
U420 Seminatural and natural areas not in use

29 Land management:
1 Visible signs of grazing
2 No signs of grazing
8 N.R.
Only if LC = BXX, CXX, DXX, EXX, FX0, HXX

30 Special remark on land cover / land use:
1 Tilled and/or sowed
2 Harvested field
3 Clear cut
4 Burnt area
5 Fire break
6 Nursery
7 No remark.

31 Special status:
1 Protected
2 Hunting
3 Protected and Hunting
4 No special status

Water management (ONLY if LU = U111 or U112)

32 Presence of water management: (Take an irrigation photo)
1 Irrigation
2 Potential irrigation
3 Drainage
4 Irrigation and drainage
5 No visible water management
8 N.R.

33 Source of irrigation:
1 Well
2 Pond/Lake/Reservoir
3 Stream/Canal/Ditch
4 Lagoon/Wastewater
5 Other/not identifiable
8 N.R.

34 Type of irrigation:
1 Gravity
2 Pressure: Sprinkler irrigation
3 Pressure: Micro-irrigation
4 Gravity/Pressure
5 Other/not identifiable
8 N.R.

35 Delivery System:
1 Canal
2 Ditch
3 Pipeline
5 Other/not identifiable
8 N.R.

Transect

42 Transect	01	02	03	04	05	06	07	08	09	10	11	12
O → → : LC codes												
length (m)												

42 Transect	13	14	15	16	17	19	19	20	21	22	23	24
O → → : LC codes												
length (m)												

01 Grass margins < 3 m
02 Heath/Shrub, tall herb fringes < 3 m
10 Single bushes, single tree
11 Avenue trees and other line of trees
12 Conifer hedges < 3 m
13 Bush/tree hedges/coppices, visibly managed (e.g. pollarded) < 3 m
14 Bush/tree hedges, not managed, with single trees, or shrubland deriving from abandonment < 3 m
15 Grove/Woodland margins (if no hedgerow) < 3 m
21 Dry stone walls
22 Artificial constructions (other than dry stone walls)
23 Fences
24 Electric lines and other aerial cables
31 Ditches, channels < 3 m
32 Rivers, streams < 3 m
41 Ponds, wetlands < 3 m
51 Rock outcrops with some natural vegetation
61 Tracks
62 Roads
63 Railways
71 Other linear elements
PI Start / End Photo-Interpretation
X Premature end of transect field assessment
8 No transect mapped

43 Remarks about the transect: (e.g. reasons for prematurely end of transect interpretation, PI circumstances)

REMEMBER TO TAKE A TRANSECT PHOTO AND MARK THE END TIME OF OBSERVATION

Photos

			Taken	Not taken	Not relevant	Photo ID	To be anonymised
44	Point	if visible	1	2	8		
45	Crop – Cover	if LC1 = B,C,D,E	1	2	8		
46	North		1	2	8		
47	East		1	2	8		
48	South		1	2	8		
49	West		1	2	8		
50	Irrigation		1	2	8		
51	Transect	if (partly) walkable	1	2	8		
53	Conflict case		1	2	8		
54	Field Form		1	2	8		

Annex 2.3 - LUCAS field form 2009

Eurostat — LUCAS 2009 (Land Use / Cover Area frame statistical Survey)

LUCAS 2009 - LAND USE / COVER AREA FRAME STATISTICAL SURVEY

Identification

A	Surveyor ID: ________	B	Point ID: ________	C	Soil sample number: ________

Observation

1	Date: __/__ (DD MM)	5	Type of observation: 1 [ ] Field survey, point visible, 0-100m to pt 2 [ ] Field survey point visible, >100 m to pt 3 [ ] Photo-interpretation, point not visible 4 [ ] The point is not observed	11	Elevation: ________ m
2	Start time: __:__ (hh mm)				
3	End time: __:__ (hh mm)	6	GPS projection system: ________	12	Distance to the point: ________ m
4	Observed: 1 [ ] The point is observed 2 [ ] Point is not visible 3 [ ] Marine sea 4 [ ] Out of national territory	7	Precision: ________ m	13	Direction: 1 [ ] on the point 2 [ ] north 3 [ ] east 8 [ ] not relevant
		8	Latitude: ________ (DD,dddddd)		
		9/10	Longitude: [ ] WE ________ (DD,dddddd)		

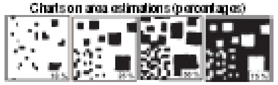
Comments

14	Description of the way to the point	15	Remarks about special circumstances (e.g. observation not at the point, ground document unclear, etc.)

Land cover and land use

16	LC1 [____]	17	LC2 [____]	18	Radius: 1 [ ] 1.5 m 2 [ ] 20 m	19	Area size (in ha): 1 [ ] area < 0.5 2 [ ] 0.5 ≤ area < 1 3 [ ] 1 ≤ area < 10 4 [ ] area ≥ 10
22	LC1 plant species: ________	23	LC2 plant species: ________				
24	Percentage of land coverage (%) LC1: 1 [ ] < 10 2 [ ] 10 ≤ LC < 25 3 [ ] 25 ≤ LC < 50 4 [ ] 50 ≤ LC < 75 5 [ ] LC ≥ 75	25	Percentage of land coverage (%) LC2: 1 [ ] < 10 2 [ ] 10 ≤ LC < 25 3 [ ] 25 ≤ LC < 50 4 [ ] 50 ≤ LC < 75 5 [ ] LC ≥ 75	20	Only if LC C00, or D10 or E10 and area size ≥0.5 ha Height of trees at maturity: 1 [ ] < 5 m 2 [ ] ≥ 5 m	21	Only if LC C00, or D10 or E10 and height of trees above 5 m and area size ≥0.5 ha Width of feature: 1 [ ] < 20 m 2 [ ] ≥ 20 m
26	LU1 [____]	27	LU2 [____]	28	Land management: 1 [ ] grazed 2 [ ] not grazed 8 [ ] not relevant		

Charts on area estimations (percentages)



produced by EFTAS

Water management

29	Presence of water management: (Only if LU = U111 or U112)	1 [ ] Irrigation 2 [ ] Potential irrigation 3 [ ] Drainage 4 [ ] Irrigation and drainage 5 [ ] No visible water management 8 [ ] not relevant	30	Source of irrigation:	1 [ ] Well 2 [ ] Pond/Lake/Reservoir 3 [ ] Stream/Canal/Ditch 4 [ ] Lagoon/Wastewater 5 [ ] Other/not identifiable 8 [ ] not relevant
31	Type of irrigation:	1 [ ] Gravity 2 [ ] Pressure: Sprinkler irrigation 3 [ ] Pressure: Micro-irrigation 4 [ ] Gravity/Pressure 5 [ ] Other/not identifiable 8 [ ] not relevant	32	Delivery System:	1 [ ] Canal 2 [ ] Ditch 3 [ ] Pipeline 4 [ ] Other/not identifiable 8 [ ] not relevant

Soil

33	Is the soil sample taken?	1 [ ] Yes 2 [ ] No 3 [ ] Not in the sample	34	Can you see any sign of ploughing in the plot?	1 [ ] Yes 2 [ ] No 8 [ ] not relevant
35	Percentage of residual crops on the surface:	1 [ ] RC < 10 2 [ ] 10 ≤ RC < 25 3 [ ] 25 ≤ RC < 50 4 [ ] RC ≥ 50 8 [ ] not relevant	36	Percentage of stones on the surface:	1 [ ] S < 10 2 [ ] 10 ≤ S < 25 3 [ ] 25 ≤ S < 50 4 [ ] S ≥ 50 8 [ ] not relevant
37	Remarks about the soil sample: (e.g. why it could not be taken, or special)				

Transect

38	Transect	
	O → →	

39	Remarks about the transect: (e.g. reasons for premature end of transect, map problems, PI circumstances)

Photos

		Taken	Not taken	Not relevant	Photo ID	To be anonymised
40	Point	1 [ ]	2 [ ]	8 [ ]	________	[ ]
41	Crop – Cover	1 [ ]	2 [ ]	8 [ ]	________	[ ]
42	North	1 [ ]	2 [ ]	8 [ ]	________	[ ]
43	East	1 [ ]	2 [ ]	8 [ ]	________	[ ]
44	South	1 [ ]	2 [ ]	8 [ ]	________	[ ]
45	West	1 [ ]	2 [ ]	8 [ ]	________	[ ]
46	Irrigation	1 [ ]	2 [ ]	8 [ ]	________	[ ]
47	Transect	1 [ ]	2 [ ]	8 [ ]	________	[ ]
48	Soil	1 [ ]	2 [ ]	8 [ ]	________	[ ]
49	Conflict case	1 [ ]	2 [ ]	8 [ ]	________	[ ]

Do not forget to take the soil, irrigation and transect and plot survey!

Do not forget to note End time of the survey!

Annex 3 – Correspondence tables linking LUCAS to the Copernicus classes

The detailed correspondence tables are attached to this report in the form of digital Microsoft Excel sheets.

Annex 4 – Summary table LUCAS LC linkages to Copernicus LC

LUCAS LC Code	LUCAS LC category	CLC		NGR		FTY; TCD		IMD		WET		Water		UA		Riparian LC		Riparian GLE	
		No [1][40]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]
A11	Buildings with one to three floors	6	5	0	0	0	0	1	0	0	0	0	0	11	0	8	0	0	0
A12	Buildings with more than three floors	5	5	0	0	0	0	1	0	0	0	0	0	11	0	6	0	0	0
A13	Greenhouses	7	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0
A21	Non built-up area features	10	5	0	0	0	0	0	1	0	0	0	0	14	0	14	0	0	0
A22	Non built-up linear features	10	5	0	0	0	0	0	1	0	0	0	0	11	0	6	0	0	0
A30	Other artificial areas	3	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
B11	Common wheat	3	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B12	Durum wheat	3	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B13	Barley	3	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B14	Rye	3	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B15	Oats	3	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B16	Maize	3	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B17	Rice	1	2	0	0	0	0	0	0	0	0	0	0	2	0	4	0	0	0
B18	Triticale	3	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0

[40] Shown are the summed up numbers of correspondence values from the detailed correspondence matrices (ANNEX).

The value of [1] means, that the LUCAS LC/LU class is more detailed as the Copernicus class, i.e. it can be used directly to validate the Copernicus class, but may not fully describe the more general Copernicus class;

2 = the LUCAS LC/LU class is more general as the Copernicus class, i.e. it can only be partially used to validate the Copernicus class.

LUCAS LC Code	LUCAS LC category	CLC		NGR		FTY; TCD		IMD		WET		Water		UA		Riparian LC		Riparian GLE	
		No [1][40]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]
B19a-h	Other cereals*	3	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B21	Potatoes	3	4	0	0	0	0	0	0	0	0	0	0	2	4	8	0	0	0
B22	Sugar beet	3	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B23a-n	Other root crops*	3	4	0	0	0	0	0	0	0	0	0	0	2	4	8	0	0	0
B31	Sunflower	3	4	0	0	0	0	0	0	0	0	0	0	2	4	8	0	0	0
B32	Rape and turnip rape	3	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B33	Soya	3	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B34	Cotton	3	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B35a-n	Other fibre and oleaginous crops*	3	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B36	Tobacco	3	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B37a-f	Other non-permanent industrial crops*	1	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B41	Dry pulses	3	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B42	Tomatoes	3	4	0	0	0	0	0	0	0	0	0	0	2	4	8	0	0	0
B43a-h	Other fresh vegetables*	3	4	0	0	0	0	0	0	0	0	0	0	2	4	8	0	0	0
B44	Floriculture and ornamental plants	3	6	0	0	0	0	0	0	0	0	0	0	3	4	6	0	0	0
B45	Strawberries	2	5	0	0	0	0	0	0	0	0	0	0	2	4	10	0	0	0
B51	Clovers	3	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B52	Lucerne	3	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B53a-k	Other leguminous and mixture for fodder*	2	4	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0
B54	Mixed cereals for fodder	2	4	0	0	0	0	0	0	0	0	0	0	2	0	7	0	0	0
B55	Temporary grassland	3	4	0	0	0	0	0	0	0	0	0	0	2	0	7	0	0	0
B71	Apple fruit	1	6	0	0	2	2	0	0	0	0	0	0	2	4	7	0	0	0
B72	Pear fruit	1	6	0	0	2	2	0	0	0	0	0	0	2	4	7	0	0	0
B73	Cherry fruit	1	6	0	0	2	2	0	0	0	0	0	0	2	4	7	0	0	0
B74	Nuts trees	1	6	0	0	2	2	0	0	0	0	0	0	2	4	7	0	0	0

LUCAS LC Code	LUCAS LC category	CLC		NGR		FTY; TCD		IMD		WET		Water		UA		Riparian LC		Riparian GLE	
		No [1][40]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]
B75a-r	Other fruit trees and berries*	1	6	0	0	0	4	0	0	0	0	0	0	2	4	7	0	0	0
B76	Oranges	1	6	0	0	2	2	0	0	0	0	0	0	2	4	7	0	0	0
B77a-k	Other citrus fruit*	1	6	0	0	2	2	0	0	0	0	0	0	2	4	7	0	0	0
B81	Olive groves	2	5	0	0	2	2	0	0	0	0	0	0	2	4	4	0	0	0
B82	Vineyards	2	5	0	0	0	0	0	0	0	0	0	0	2	0	4	0	0	0
B83	Nurseries	0	0	0	0	2	2	0	0	0	0	0	0	2	0	4	0	0	0
B84a-m	Permanent industrial crops*	1	5	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0	0
C10	Broadleaved woodland	4	6	0	0	3	2	0	0	0	0	0	0	5	5	9	3	1	0
C20	Coniferous woodland	4	6	0	0	2	2	0	0	0	0	0	0	5	5	9	3	1	0
C21	Spruce dominated coniferous woodland	4	6	0	0	0	0	0	0	0	0	0	0	5	5	9	3	1	0
C22	Pine dominated conifer-ous woodland	4	6	0	0	0	0	0	0	0	0	0	0	5	5	9	3	1	0
C23	Other coniferous woodland	4	6	0	0	0	0	0	0	0	0	0	0	5	5	9	3	1	0
C30	Mixed woodland	4	6	0	0	3	2	0	0	0	0	0	0	5	5	9	7	1	0
C31	Spruce dominated mixed woodland	4	6	0	0	0	0	0	0	0	0	0	0	5	5	9	5	1	0
C32	Pine dominated mixed woodland	4	6	0	0	0	0	0	0	0	0	0	0	5	5	9	5	1	0
C33	Other mixed woodland	4	6	0	0	0	0	0	0	0	0	0	0	5	5	9	5	1	0
Cxx1	Boreal forest	0	0	0	0	0	0	0	0	0	0	0	0	5	5	3	1	0	0
Cxx2	Hemiboreal forest and nemoral coniferous forest and mixed broadleaved-coniferous forest	0	0	0	0	0	0	0	0	0	0	0	0	5	5	1	3	0	0
Cxx3	Alpine coniferous forest	0	0	0	0	0	0	0	0	0	0	0	0	5	5	1	1	0	0
Cxx4	Acidophilous oak and	0	0	0	0	0	0	0	0	0	0	0	0	5	5	1	1	0	0

LUCAS LC Code	LUCAS LC category	CLC		NGR		FTY; TCD		IMD		WET		Water		UA		Riparian LC		Riparian GLE	
		No [1][40]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]
	oak-birch forest																		
Cxx5	Mesophytic deciduous forest	0	0	0	0	0	0	0	0	0	0	0	0	5	5	1	1	0	0
Cxx6	Beech forest	0	0	0	0	0	0	0	0	0	0	0	0	5	5	1	1	0	0
Cxx7	Mountainous beech forest	0	0	0	0	0	0	0	0	0	0	0	0	5	5	1	1	0	0
Cxx8	Thermophilous decidu-ous forest	0	0	0	0	0	0	0	0	0	0	0	0	5	5	1	1	0	0
Cxx9	Broadleaved evergreen forest	0	0	0	0	0	0	0	0	0	0	0	0	5	5	1	1	0	0
CxxA	Coniferous forest of the Mediterranean region	0	0	0	0	0	0	0	0	0	0	0	0	5	5	1	1	0	0
CxxB	Mire and swamp forests	0	0	0	0	0	0	0	0	0	0	0	0	5	5	2	1	0	0
CxxC	Floodplain forest	0	0	0	0	0	0	0	0	0	0	0	0	5	5	1	1	0	0
CxxD	Non-riverine alder, birch or aspen forest	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0	0	0	0
CxxE	Exotic forest	0	0	0	0	0	0	0	0	0	0	0	0	5	5	3	2	0	0
D10	Shrubland with sparse tree cover	1	8	0	0	0	1	0	0	0	0	0	0	7	1	7	3	1	0
D20	Shrubland without tree cover	1	8	0	0	0	0	0	0	0	0	0	0	7	1	7	3	1	0
E10	Grassland with sparse tree/shrub cover	7	7	1	0	1	0	0	0	0	0	0	0	10	5	13	3	2	0
E20	Grassland without tree/shrub cover	7	7	1	0	0	0	0	0	0	0	0	0	10	5	13	3	0	0
E30	Spontaneously re-vegetated surfaces	4	9	1	0	0	0	0	0	0	0	0	0	6	5	6	0	0	0
F10	Rocks and stones	9	3	0	0	0	0	0	0	0	0	0	0	7	5	6	1	0	0
F20	Sand	8	4	0	0	0	0	0	0	0	0	0	0	7	5	5	3	0	0
F30	Lichens and Moss	10	4	0	0	0	0	0	0	0	0	0	0	7	5	3	0	0	0
F40	Other bare soil	10	12	0	0	0	0	0	0	0	0	0	0	7	5	5	1	0	0

LUCAS LC Code	LUCAS LC category	CLC		NGR		FTY; TCD		IMD		WET		Water		UA		Riparian LC		Riparian GLE	
		No [1][40]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]	No [1]	No [2]
G11	Inland fresh water bodies	6	9	0	0	0	0	0	0	0	0	1	0	3	4	8	0	0	0
G12	Inland salty water bodies	6	4	0	0	0	0	0	0	0	0	1	0	3	4	4	0	0	0
G21	Inland fresh running water	2	6	0	0	0	0	0	0	0	0	1	0	2	4	3	0	0	0
G22	Inland salty running water	2	3	0	0	0	0	0	0	0	0	1	0	2	4	1	0	0	0
G30	Transitional water bodies	0	4	0	0	0	0	0	0	0	1	1	0	1	0	1	0	0	0
G50	Glaciers, permanent snow	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
H11	Inland marshes	1	1	0	0	0	0	0	0	1	0	0	0	1	0	3	0	0	0
H12	Peatbogs	1	1	0	0	0	0	0	0	1	0	0	0	1	0	4	0	0	0
H21	Salt-marshes	1	1	0	0	0	0	0	0	1	0	0	0	1	0	4	0	0	0
H22	Salines and other chemical deposits	1	2	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0
H23	Intertidal flats	1	1	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0

* further separated according to LC plant list

Annex 5 – Summary LUCAS class recommendation

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
CLC	A11, A12	U370 U410	111	2	No precise definition of CLC111 and 112 is possible, because they are determined by built-up densities only if >80% built up		Add parameter for extended 20m window, such as %impervious in groups (e.g. by 10% intervals)
CLC	A21, A22	U370 U34x U410	111	2	U410 only if <25 ha No precise definition of CLC111 and 112 is possible, because they are determined by built-up densities		Add parameter for extended 20m window, such as %impervious in groups (e.g. by 10% intervals)
CLC	B44	U370	111	2	No precise definition of CLC111 and 112 is possible, because they are determined by built-up densities Only if total built-up density is >80%		Add parameter for extended 20m window, such as %impervious in groups (e.g. by 10% intervals)
CLC	A11, A12	U370 U410	112	2	No precise definition of CLC111 and 112 is possible, because they are determined by built-up densities Only if 30-80% built up		Add parameter for extended 20m window, such as %impervious in groups (e.g. by 10% intervals)
CLC	A21, A22	U370 U410	112	2	U410 only if <25 ha	Limited usage of LUCAS LU=410, due to CLC 25ha MMU and generalisation rules.	
CLC	A11, A12, A21, A22	U317	123	2	CLC123 includes also storage areas and fuel tanks/oil terminals associated to ports, as well as military and recreation ports (marinas)		Recommend to record LU2 in case of U317 and other LUs in case if point belongs to port area (U313), airport area (U314), ….
CLC	Exx, Fxx	U313	123	2	CLC123 includes only port/harbour areas (but not channels, rivers etc.), but in contrary to LUCAS U313 CLC123 includes also storage areas and fuel tanks/oil terminals associated to ports, as well as military (U350) and recrea-tion ports (U362)		Recommend to record LU2 in case of U317 and other LUs in case if point belongs to port area (U313), airport area (U314), ….

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
CLC	G11, G12, G21, G22, G30	U313	123	2	Only within ports, if ports otherwise does not reach 25 ha size (CLC Techni-cal Addendum p. 38)	Limited usage due to CLC 25ha MMU and generalisation rules.	Recommend to record LU2 in case of U317 and other LUs in case if point belongs to port area (U313), airport area (U314) ….
CLC	A11, A12, A21, A22	U314	124	2	CLC includes also storage areas and terminals associated to airports, as well as adjacent grass areas.		Recommend to record LU2 in case of U317 and other LUs in case if point belongs to port area (U313), airport area (U314) ….
CLC	Exx, Fxx	U314	124	2	CLC includes also storage areas and terminals associated to airports, as well as adjacent grass areas.		Recommend to record LU2 in case of U317 and other LUs in case if point belongs to port area (U313), airport area (U314) ….
CLC	A11, A12, A21, A22, E30, Fxx	U140	131	2	CLC131 excludes peat extraction	-	Subdivision of U140 to distinguish peat extraction, salines (not equal to salt min-ing)….
CLC	B44, B7x, B81, B82	U361	141	2	U361 combines land uses represented by CLC141 and 142		U361: Create separate LU class for leisure, e.g.: - U361 (new) Amenities + leisure - U362 (remains) Sport - U363 (new) culture & museum… => CLC142 = U361+U362 Additional parameter for CLC 141 needed if U36x "urban/non-urban context"
CLC	E10, E20	U36x	141	2	If dominated by green and inside urban fabric	-	U361: Create separate LU class for leisure, e.g.: - U361 (new) Amenities + leisure - U362 (remains) Sport - U363 (new) culture & museum… => CLC142 = U361+U362 Additional parameter for CLC 141 needed if U36x "urban/non-urban context"

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
CLC	G11, G12	U36x	141	2	If inside urban fabric	-	U361: Create separate LU class for leisure, e.g.: - U361 (new) Amenities + leisure - U362 (remains) Sport - U363 (new) culture & museum… => CLC142 = U361+U362 Additional parameter for CLC 141 needed if U36x "urban/non-urban context"
CLC	B44, B7x, B81, B82	U361	142	2	U361 combines land uses represented by CLC 141 and 142	-	U361: Create separate LU class for leisure, e.g.: - U361 (new) Amenities + leisure - U362 (remains) Sport - U363 (new) culture & museum… => CLC142 = U361+U362 Additional parameter for CLC 141 needed if U36x "urban/non-urban context"
CLC	G11, G12	U361/U362	142	2	If <25 ha, otherwise CLC 512		U361: Create separate LU class for leisure, e.g.: - U361 (new) Amenities + leisure - U362 (remains) Sport - U363 (new) culture & museum… => CLC142 = U361+U362 Additional parameter for CLC 141 needed if U36x "urban/non-urban context"
CLC	G21, G22	U361/U362	142	2	If <25 ha and <100m width otherwise CLC 511		U361: Create separate LU class for leisure, e.g.: - U361 (new) Amenities + leisure - U362 (remains) Sport - U363 (new) culture & museum… => CLC142 = U361+U362 Additional parameter for CLC 141 needed if U36x "urban/non-urban context"

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
CLC	G30	U361/U362	142	2	Only if <25ha, otherwise CLC 521 or CLC 522		U361: Create separate LU class for leisure, e.g.: - U361 (new) Amenities + leisure- U362 (remains) Sport - U363 (new) culture & museum…=> CLC142 = U361+U362Additional parameter for CLC 141 needed if U36x "urban/non-urban context"
CLC	Bxx	-	211	-	CLC211 cannot be properly described in LUCAS, because irrigation is missing. Irrigation is not a land use form, but a land cultivation measure. To the analogue of EAGLE database it might be useful to add characteristics like that to LUCAS (also applicable for CLC334 class)	Irrigation/drainage is also ob-served at the LUCAS points and categorised e.g. irrigation by channel/pond etc. This can be used to retrieve irrigation infor-mation.	
CLC	B37a,c,d,e,f	U111	211	1	Hop (B37b) is not included in CLC 211	Exclude B37b from comparison with CLC 211.	
CLC	F40	U111/U112	211	2	If arable land or fallow of arable land CLC211 includes only arable land, U111 also other agricultural land	Considering the combinations of LC1/LC2 with LU1/LU2 it is possi-ble to evaluate whether a point falls on 'arable' land or not. The specific combination LC1 F40/ U111 is always arable land in LUCAS (C3 p.60).	
CLC	G11, G21	U111	211	2	Irrigation ponds, drainage canals on arable land	Irrigation/drainage is also ob-served at the LUCAS points and categorised e.g. irrigation by channel/pond etc. This can be used to retrieve irrigation infor-mation.	
CLC	G12	-	211	0	Although LUCAS would allow the G12+U111 combination, in CLC irriga-tion with salt water is excluded by logic.		Exclude option G12/U111 from C3 LUCAS nomenclature.

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
CLC	Bxx	-	212	-	CLC212 cannot be properly described in LUCAS. Irrigation is not a land use form, but a land cultivation measure. To the analogue of EAGLE database it might be useful to add characteristics like that to LUCAS (also applicable for CLC334 class)	In LUCAS irrigation is already observed (if LU is U111/U112) at the LUCAS point and can thus be used to validate irrigation.	
CLC	B37b	U111	212	2	Hop is not included in CLC 212	Exclude B37b from comparison with CLC 212.	
CLC	F40	U111	212	2	If irrigated arable land	Considering the combinations of LC1/LC2 with LU1/LU2 it is possi-ble to evaluate whether a point falls on 'arable' land or not. The specific combination LC1 F40/ U111 is always arable land in LUCAS (C3 p.60).	
CLC	G11, G21	U111	212	2	Irrigation ponds and canals on irrigated arable land	Irrigation/drainage is also ob-served at the LUCAS points and categorised e.g. irrigation by channel/pond etc. This can be used to retrieve irrigation infor-mation.	
CLC	F40	U111	213	2	If land under rice production	Landscape photos taken at the LUCAS point can assist interpreta-tion. If rice is detected LUCAS LC class will be B17	
CLC	G21	U111	213	2	Irrigation canals	Irrigation/drainage is also ob-served at the LUCAS points and categorised e.g. irrigation by channel/pond etc. This can be used to retrieve irrigation infor-mation.	
CLC	B82	U111	221	1	>50% occupancy	The percentage of land cover can be used.	

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
CLC	F40	U111	221	2	Bare soil among vineyards	Vineyards B82 are assed within the extended observation window (20m radius), thus ONLY if there is a spot with a 20m radius of bare soil in a vineyard, will the pure code F40/ U111 not reveal that the point is in a vineyard. This is probably a very rare case. In all other cases of smaller spots of bare soil the LUCAS point will be coded B82/U111.	
CLC	G11	U111	221	2	Irrigation ponds in vineyards	Landscape photos taken at the LUCAS point can assist interpreta-tion.	
CLC	B37	U111	222	2	Hop is included in CLC222, other industrial crops not 0:B37a,c,d,e,f	add B37b to B70 and B80 (exclu-sive B83) for comparison with CLC 222	
CLC	B7x	U111	222	2	>50% occupancy	The percentage of land cover can be used.	
CLC	F40	U111	222	2	Bare soil among fruit trees/shrubs	Fruit trees/shrubs (B7x) are assessed within the extended observation window (20m radius), thus ONLY if there is a spot with a 20m radius of bare soil, will the F40/ U111 not reveal that the point is within fruit trees. This is probably a very rare case. In cases of smaller spot of bare soil the LUCAS point will be coded B7x/U111.	
CLC	G11	U111	222	2	Irrigation ponds in fruit plantations	Landscape photos taken at the LUCAS point can assist interpreta-tion.	

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
CLC	F40	U111	223	2	Bare soil among olive trees	Olive trees (B81) are assessed within the extended observation window (20m radius), thus ONLY if there is a spot with a 20m radius of bare soil, will the F40/ U111 not reveal that the point is within an olive plantation. This is probably a very rare case. In cases of smaller spot of bare soil the LUCAS point will be coded B81/U111 anyway.	
CLC	G11	U111	223	2	Irrigation ponds in olive plantations	Landscape photos taken at the LUCAS point can assist interpreta-tion.	
CLC	C10, C2x, C3x	U111	231	2	CLC can contain 10-20% tree/shrub cover	The percentage of land cover can be used. If there is a woodland (>10% canopy cover) with grass-land and LU U111 below it will be coded as LC2/LU2	
CLC	D10	U111 U112	231	2	CLC can contain 10-20% tree/shrub cover	The percentage of land cover can be used. If there is a woodland (>10% canopy cover) with grassland and LU U111 below it will be coded as LC2/LU2	
CLC	Bxx (except B17 and B83f)	U111	241	2	If mixed on the same parcel with permanent crops Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, partly because of very different MMU, partly because the specific spatial pattern of CLC241 is missing.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
CLC	E30	U111	241	2	If mixed on the same parcel with arable crops Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, partly because of very different MMU, partly because the specific spatial pattern of CLC241 is missing.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	
CLC	F40	U111 U112	241		Bare soil (arable land) intermixed with permanent crops on the same parcel Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, partly because of very different MMU, partly because the specific spatial pattern of CLC241 is missing.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	
CLC	B7x	U111 U113	242	2	If in mosaic with arable parcels/pasture Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, partly because of very different MMU, partly because the specific spatial pattern of CLC241 is missing.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	
CLC	E10	U111	242	2	If in mosaic with arable land/permanent crops Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	
CLC	F40	U111 U112	242	2	If in mosaic with pastures/permanent crops Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
CLC	Bxx, B83	U111	243	2	If in mosaic with natural vegetation Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	
CLC	C10, C2x, C3x	U111 U120	243	2	If in mosaic with agricultural parcels Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	
CLC	D10, D20	U111 U112 U120 U420	243	2	If in mosaic with agricultural parcels Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	
CLC	E10, E20	U111 U120 U4x0	243	2	If in mosaic with agricultural parcels Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	
CLC	E30	U112	243	2	If in mosaic with agricultural parcels Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	
CLC	F10, F20, F30	U4x0	243	2	If in mosaic with agricultural parcels Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos	

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
						can assist further interpretation.	
CLC	F40	U111 U4x0	243	2	If in mosaic with agricultural parcels Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	
CLC	G11	U111 U130 U4x0	243	2	If in mosaic with agricultural parcels Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	
CLC	G12	U130 U4x0	243	2	If in mosaic with agricultural parcels Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	
CLC	G21	U111 U130 U140 U313 U4x0	243	2	If in mosaic with agricultural parcels Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	
CLC	G22	U130 U140 U313 U4x0	243	2	If in mosaic with agricultural parcels Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
CLC	H11	U321 U4x0	243	2	If in mosaic with agricultural parcels Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	
CLC	H12	U140 U4x0	243	2	If in mosaic with agricultural parcels Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	
CLC	H21	U111 U4x0	243	2	If in mosaic with agricultural parcels Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	
CLC	H22	U410	243	2	If in mosaic with agricultural parcels Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	
CLC	H23	U130 U420	243	2	If in mosaic with agricultural parcels Mosaic classes of CLC (241, 242, 243) cannot be described by LUCAS, because of very different MMU.	Due to the CLC MMU of 25ha and the underlying generalisation rules, LUCAS LC/LU classes can only be used to identify CLC class components. Landscape photos can assist further interpretation.	

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
CLC	B1x (except B17) B2x B3x B4x (except B44) B5x	U111	244	2	If mixed on the same parcel with forestry trees (dehesa) CLC244 cannot be properly described in LUCAS, because agro-forestry as land cultivation form is missing. See also comment at CLC212.	Can be detected by considering LUCAS LC1 = Cx and LC2=Bx (with U111). If there is a second LU in a forest, e.g. grazing animals there are two LC and two LU given.	
CLC	C10 C2x C3x	U111	244	2	Between 10-30% canopy cover + if mixed on the same parcel with arable crops. CLC244 cannot be properly described in LUCAS, because agro-forestry as land cultivation form is missing. See also comment at CLC212.	Can be detected by considering LUCAS LC1 = Cx and LC2=Bx (with U111). If there is a second LU in a forest, e.g. grazing animals there are two LC and two LU given. The percentage of land cover is also recorded in LUCAS.	
CLC	E10, E20	U111	244	2	Grazed grassland among scattered trees (10-30%) in agroforestry areas. CLC244 cannot be properly described in LUCAS, because agro-forestry as land cultivation form is missing. See also comment at CLC212.	Can be detected by considering LUCAS LC1 = Cx and LC2=Ex (with U111). If there is a second LU in a forest, e.g. grazing animals there are two LC and two LU given.	
CLC	E30	U112	244	2	On agro-forestry areas CLC244 cannot be properly described in LUCAS, because agro-forestry as land cultivation form is missing. See also comment at CLC212.	Can be detected by considering LUCAS LC1 = Cx and LC2=Ex (with U111). If there is a second LU in a forest, e.g. grazing animals there are two LC and two LU given.	
CLC	F40	U111 U112	244	2	Bare arable land in agroforestry areas CLC244 cannot be properly described in LUCAS, because agro-forestry as land cultivation form is missing. See also comment at CLC212.	Can be detected by considering LUCAS LC1 = Cx and LC2=F40 (with U111/U112). If there is a second LU in a forest, e.g. grazing animals there are two LC and two LU given.	
CLC	C10, C2x	U120	311	2	CLC311: >30% canopy cover	The percentage of land cover can be used. A Cxx Class is in LUCAS if there are >10% tree canopy.	Harmonize land cover % assessment to 10% intervals

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
CLC	C3x	U120	313	2	CLC313: >30% crown cover	The percentage of land cover can be used. A Cxx Class is in LUCAS if there are >10% tree canopy.	Harmonize land cover % assessment to 10% intervals
CLC	C10, C2x, C3x	U420	321	2	Between 10-30% canopy cover	The percentage of land cover can be used. A Cxx Class is in LUCAS if there are >10% tree canopy.	Harmonize land cover % assessment to 10% intervals
CLC	D10, D20	U420	321	2	<25% woody cover	The percentage of land cover can be used. Usable if LUCAS percent-age of land coverage = 10-25%.	Increase class details for shrubs. E.g. ana-logue to forest types
CLC	D10, D20	U420	322	2	Only moors/heathland, but not Medi-terranean shrub		Increase class details for shrubs. E.g. ana-logue to forest types, here: CLC 322 includes temperate shrubby vegeta-tion (e.g. heathland, alpine scrub, brown dunes…) excludes mattoral vegetation (maquis, garrique…)
CLC	D10, D20	U420	323	2	Only Mediterranean shrub, but not moors/heathland Differentiation between CLC shrub types is not possible.		Increase class details for shrubs. E.g. ana-logue to forest types. CLC 323 represents bushy sclerophyllous vegetation and includes mattoral vegetation (maquis and garrigue)
CLC	D10, D20	U120 U112 U420	324	2	Only transitional shrubland, but not climax-stage woody vegetation associa-tions (such as heathland or Mediterra-nean shrub).		Increase class details for shrubs. E.g. ana-logue to forest types. Here distinction between climax and transitional shrubland (turning ultimately into forest vegetation)
CLC	F20	U362 U4x0	331	2	U362 only for natural seashores and river banks used also for recreational purposes, but not for sand covered sports fields in other context.	Landscape photos taken at the LUCAS point can assist interpreta-tion.	Add bare land types to Fxx: beach, dune, river banks.
CLC	D10, D20	U420	333	2	Between 10-50% vegetation cover.	The percentage of land cover can be used.	Add Ex as LC2 even without second LU.
CLC	F30	U420	333	2	10-50% vegetation cover	The percentage of land cover can be used.	

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
CLC	F40	U120 U40x	334	1	Freshly burnt areas on former natural woody vegetation/forest CLC334 cannot be properly described in LUCAS. Fire damage is not a land cover, but a type of damage. To the analogue of EAGLE database it might be useful to add characteristics like that to LUCAS (also applicable for CLC212 class)	There is a remark field 37 in LUCAS 'burnt area'	
CLC	G50	U361 U362 U420	335	1	Definition difference. CLC: extent measures glacier at smallest extent in season; LUCAS measures glaciers at largest extent in season.		Harmonize glacier definitions.
CLC	C10, C2x, C3x	U420	411	2	Between 10-30% canopy cover	The percentage of land cover can be used.	Harmonize land cover % assessment to 10% intervals
CLC	D10, D20	U420	412	2	If in peatbogs	The percentage of land cover can be used.	
CLC	H22	U140	422	2	Salines cannot be properly described in LUCAS.		Subdivision of U140 to distinguish peat extraction, salines (not equal to salt min-ing)....
CLC	G30	U420	521	2	CLC refers only to lagoons.		Apply new special remark in LUCAS (lagoon, estuary)
CLC	G30	U420	522	2	CLC refers only to estuaries.		Apply new special remark in LUCAS (lagoon, estuary)
CLC			523	2	Sea/ocean is not covered by LUCAS.		
TCD	B75a-r	U111 U113 U361 U410	1-100 tree cover density values (TCD)	2	TCD refers only to trees.		Split B75 into two classes (B75 a-x Other fruit trees / B75x-k Other berries) in order not to mix trees and shrubs in this class.

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
TCD	D10	U111, U112, U120, U36x, U420	1-100 tree cover density values (TCD)	2	Included if tree cover can be detected from the 20m rastered imagery per pixel	In LUCAS D10 shrubs have to cover more than 10% and trees <10%. Land coverage percentage of trees is per definition between 5-10%. LC1 coverage percentage refers to shrubs. The width of feature attribute describes the geometry (< or > 20x20m). If the width of a feature is below 20x20m, it is not recom-mended to use the data for TCD validation.	
FTY	C3x	U111, U120, U341, U350, U36x, U370, U420	3 mixed forest (FTY)	1	exists only in aggregated 100 m product, same rules as in CLC/LUCAS	In LUCAS 2015 there is a specific % check in 5% steps. This INSPIRE results can be used to check the % of coniferous/broadleaved trees in 5% steps. This is relevant for the FTY with 50-75% conifer-ous/broadleaved in 20m product. The C3x class can be directly applied to the mixed forest type in the 100m product.	
FAD	B7x, B81, B83	U113	trees in urban context (FAD)	2	Only in urban context (according to CLC141, IMD) + only trees	-	For FAD product additional parameter needed, if point in "urban/non-urban con-text".
FAD	C1x, C2x, C3x	U341, U350, U36x, U370, U420	trees in urban context (FAD)	2	Only in urban context (according to CLC141, IMD) + only trees	-	For FAD product additional parameter needed, if point in "urban/non-urban con-text".
IMD	A13	-	1-100 imper-viousness values (IMD)	0	not defined	If A13 is part of the HRL definition (unclear yet!) it can be used.	Add parameter for extended 20m window, such as %impervious in groups (e.g. by 10% intervals)

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
IMD	A21	any	1-100 imper-viousness values (IMD)	2	Only sealed surfaces	LC2 can be used to see if an A21/A22 area is sealed. If LC2 is not given, the area can be consid-ered as mainly sealed.	Add parameter for extended 20m window, such as %impervious in groups (e.g. by 10% intervals)
IMD	A22	any (other than U311)	1-100 imper-viousness values (IMD)	2	Only sealed surfaces	LC2 can be used to see if an A21/A22 area is sealed. If LC2 is not given, the area can be consid-ered as mainly sealed.	Add parameter for extended 20m window, such as %impervious in groups (e.g. by 10% intervals)
IMD	A30	U210 U311 U312 U318 U321	1-100 imper-viousness values (IMD)	2	Excluding open dump sites + only if sealed	It is recommended not to use A30 for IMD validation, due to the very heterogeneous nature of this class.	
UA	A11	U370 U410	11100	1	Inclusion will depend on the density of these buildings, not so much the type		Add parameter for extended 20m window, such as %impervious in groups (e.g. by 10% intervals)
UA	A12	U370 U410	11100	1	Inclusion will depend on the density of these buildings, not so much the type		Add parameter for extended 20m window, such as %impervious in groups (e.g. by 10% intervals)
UA	Bxx (only some classes!)	U113 or U370	11210	2	LC component due to MMU, but not part of definition.	It is not recommended not to use this LUCAS class, because it is not part of the UA class definition and only relevant due to the UA generalisation MMU of 0.25ha.	
UA	Cxx, Exx, Fxx, G1x, G2x	U370	11210	2	LC component due to MMU, but not part of definition.	It is not recommended not to use this LUCAS class, because it is not part of the UA class definition and only relevant due to the UA generalisation MMU of 0.25ha.	
UA	Bxx (only some classes!)	U113 or U370	11220	2	LC component due to MMU, but not part of definition.	It is not recommended not to use this LUCAS class, because it is not part of the UA class definition and only relevant due to the UA generalisation MMU of 0.25ha.	

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
UA	Cxx, Exx, Fxx, G1x, G2x	U370	11220	2	LC component due to MMU, but not part of definition.	It is not recommended not to use this LUCAS class, because it is not part of the UA class definition and only relevant due to the UA generalisation MMU of 0.25ha.	
UA	Bxx (only some classes!)	U113 or U370	11230	2	LC component due to MMU, but not part of definition.	It is not recommended not to use this LUCAS class, because it is not part of the UA class definition and only relevant due to the UA generalisation MMU of 0.25ha.	
UA	Cxx, Exx, Fxx, G1x, G2x	U370	11230	2	LC component due to MMU, but not part of definition.	It is not recommended not to use this LUCAS class, because it is not part of the UA class definition and only relevant due to the UA generalisation MMU of 0.25ha.	
UA	Bxx (only some classes!)	U113 or U370	12340	2	LC component due to MMU, but not part of definition.	It is not recommended not to use this LUCAS class, because it is not part of the UA class definition and only relevant due to the UA generalisation MMU of 0.25ha.	
UA	Cxx, Exx, Fxx, G1x, G2x	U370	12340	2	LC component due to MMU, but not part of definition.	It is not recommended not to use this LUCAS class, because it is not part of the UA class definition and only relevant due to the UA generalisation MMU of 0.25ha.	
UA	Cxx, Dxx, Exx, Fxx	U317	12300	2	In case of "associated land"		Recommend to record LU2 in case of U317 and other LUs in case if point belongs to port area (U313), airport area (U314)…

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
Riparian_LC	C10, CxxC	U120 U420	3.1.1.1	2	All values 2 in the forest domain has to deal with other geographical areas. The Riparian classes are more (geographi-cally/landscape limited)	It is recommended to use the LUCAS LC forest types for the comparison with different Ripar-ian Zone forest types. LUCAS forest types are given when the woodland is >0.5 ha, the width of feature >20 m and height of maturity >5 m. C10C represents Floodplain Forest, which definition mainly overlaps with the description of 3.1.1.1	
Riparian_LC	Cxx4, Cxx5, Cxx6, Cxx7, Cxx8, Cxx9, CxxE	U120 U420	3.1.1.1	2	Riparian LC 3.1.1.1 definition also includes highly artificial broadleaved plantations and broadleaved evergreen forest that are located inside the Potential Riparian Zone	Only use LUCAS forest types within the spatial boundaries (Riparian Zone) as defined by the Copernicus layer.	
	Cxx1, Cxx2, Cxx3, CxxA, CxxE	U120 U420	3.2.1.1	2	Riparian LC 3.2.1.1 definition also includes highly artificial coniferous plantations and that are located inside the Potential Riparian Zone	Only use LUCAS forest types within the spatial boundaries (Riparian Zone) as defined by the Copernicus layer.	
Riparian_LC	Cxx	U111	4.1.1.1, 4.2.1.1, 4.2.1.2	2	HRL definitions starts with TCD>30%.	Only LUCAS Cxx points with TCD>30% can be used.	
Riparian_LC	E10/E20	U111	4.1.1.2, 4.2.2.1, 4.2.2.3	2	All values 2 in the grassland domain has to deal with other geographical areas/conditions. The Riparian classes are more (geographically/landscape limited)	Temporary grasslands are ex-cluded from Exx. LUCAS Exx contain less than 10% (E10) or 5% (E20) tree/shrub coverage. In contrast for HRL <30% tree coverage is allowed.	Add grassland types to Exx, such as dry, wet, alpine. A distinction is made between managed and semi/natural/natural grassland (all with/without tress <>30%). In relation to semi-natural grasslands there is a division between dry, mesic and alpine grasslands, according to EUNIS habitat types (E1-6, B1.19).
Riparian_LC	Dxx	U360 U420	5.1.1.1	2	Species distribution is more specific in the Riparian classes 511* and 5211		Increase class details for shrubs. E.g. ana-logue to forest types. Here differentiation between a) Heathlands and Moorlands (related to EUNIS F1, F3, F4, F8,F9) and b)

Copernicus Compo-nent	LUCAS LC Code	LUCAS LU Code	Copernicus Class	Corre-spondence value	Challenges to apply LUCAS for specific Copernicus class	Recommendations to use LUCAS in Copernicus	Recommendation to adapt LUCAS
							Other scrub land (EUNIS F2) and c) Sclero-phyllous vegetation (EUNIS F5,F6,F7) is needed
Riparian_LC	Dxx	U420	5.1.1.2, 5.2.1.1	2	Species distribution is more specific in the Riparian classes 511* and 5211		Increase class details for shrubs. E.g. ana-logue to forest types. Here differentiation between a) Heathlands and Moorlands (related to EUNIS F1, F3, F4, F8,F9) and b) Other scrub land (EUNIS F2) and c) Sclero-phyllous vegetation (EUNIS F5,F6,F7) is needed
Riparian_LC	F20	U360 U420	6.2.1.1, 6.2.1.2	2	All values 2 in the 62** domain has to deal with other geographical ar-eas/conditions/specifities. The Riparian classes are more (geographi-cally/landscape limited)		Add bare land types to Fxx. Here needed beach, dune, river banks.
Riparian_LC	F10/F20/F40	U360 U420	6.2.1.3	2	All values 2 in the 62** domain has to deal with other geographical ar-eas/conditions/specifities. The Riparian classes are more (geographi-cally/landscape limited)		Add bare land types to Fxx. Here needed beach, dune, river banks.
Riparian_LC	Dxx/Exx	U4x0	6.2.2.2	1	All values 2 in the 62** domain has to deal with other geographical ar-eas/conditions/specifities. The Riparian classes are more (geographi-cally/landscape limited)	There is a remark field (no 37) in LUCAS indicating 'burnt areas'.	

Legal notice

The contents of this publication were created by EFTAS and partners under EEA service contract No. 3436/B2015/R0-GIO/EEA.56166 and do not necessarily reflect the official opinions of the European Commission or other institutions of the European Union. Neither the European Environment Agency nor any person or company acting on behalf of the Agency is responsible for the use that may be made of the information contained in this report.

Copyright notice