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Integrating statistical and geographical information: LUCAS survey, a case study for land monitoring in European Union

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Abstract and Paper

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LUCAS results are also used for validation and calibration of the High Resolution Layers of Copernicus program as the statistical approach is complementary to the remote sensing approach.

The latest LUCAS survey, carried out in spring - summer 2015, covers all the 28 EU countries and observations on more than 270 000 points.

The paper illustrates the use of auxiliary information in the LUCAS survey design. Particular emphasis is given to the role of aerial images during the LUCAS data production process: stratification of the master sample, preparation of ground documents, and quality control. A specific chapter is dedicated to the treatment of excluded areas, areas difficult to be accessed, by means of photo-interpretation.

In the final part, in view of the next LUCAS 2018, the adaptation in terms of sample selection and classification, needed for an efficient interaction with Copernicus production process is described.

The paper shows an example of integrating field survey and remote sensing in the context of the LUCAS survey.

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Session: Optimizing Data Collection Management

Integrating statistical and geographical information: LUCAS survey, a case study for land monitoring in European Union

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**The views and opinions expressed in this article are those of the author and do not necessarily reflect the official policy or position of any institution the author belongs to.*

Abstract

Since 2006, Eurostat carries out an area frame statistical survey on the state and the dynamics of land use and cover in the European Union called the LUCAS survey (Land Use/Cover Area Frame Survey). The LUCAS surveys are completed in-situ every three years. LUCAS provides information for monitoring a range of socio-environmental challenges, such as land take, soil degradation, and the environmental impact of agriculture or the degree of landscape fragmentation.

LUCAS results are also used for validation and calibration of the High Resolution Layers of Copernicus program as the statistical approach is complementary to the remote sensing approach.

The latest LUCAS survey, carried out in spring - summer 2015, covers all the 28 EU countries and information on around 340 000 points, either visited by field surveyors (more than 270 000 points) or photo-interpreted in the office).

The paper illustrates the use of auxiliary information in the LUCAS survey design. Particular emphasis is given to the role of aerial images during the LUCAS data production process: stratification of the master sample, preparation of ground documents, and quality control. A specific chapter is dedicated to the treatment of excluded areas, areas difficult to be accessed, by means of photo-interpretation.

In the final part, in view of the next LUCAS 2018, hints to the adaptation in terms of sample selection and classification, needed for an efficient interaction with Copernicus production process are given. In a broader framework the potential of LUCAS for the INCA (Integrated system for Natural Capital and ecosystem services Accounting) project is described.

The paper shows an example of integrating field survey and remote sensing in the context of the LUCAS survey.

Keywords: area frame survey; statistical and geographical information; land cover and land use; auxiliary information and photo- interpretation

1. Introduction

Changes in land cover, biophysical attributes of the earth's surface, and land use, human purpose or intent applied to these attributes, significantly affect key aspects of Earth System functioning. The capability of monitoring those changes is linked to the availability of information on the coverage and the use of the land. Possible sources for land cover and land use information can be geographical, statistical or administrative; traditional approaches for land monitoring make use of remote sensing, field surveys or, to a lesser extent, administrative registers. There are relevant characteristics in each methodology and given the growing demand for data on land, widely used for policy planning and evaluation in many domains, the trend is in favour of an integrated approach of the different sources to get the required quality (coverage, level of detail, accuracy, periodicity, comparability). The

soundness of LUCAS (Land Use/Cover Area frame statistical Survey) survey stays in the unique in-situ information that is can provide: both in terms of level of detail of the classification, both for the specificity of the parameters collected. It is a harmonised in-situ land data collection exercise extending across the whole of European Union, based on a standard survey methodology (two phase sampling, classifications, data collection processes). LUCAS is a flexible multipurpose platform allowing the collection of specific ad-hoc modules according to policy needs.

There is already lot of interaction between different approaches for land monitoring at European level and this paper shows how geographical and auxiliary information are currently used in the statistical framework of the LUCAS and how the synergies can be optimised to improve the performance of complementary programmes such as LUCAS and Copernicus[1]. Administrative sources are not addressed in the paper.

After a first chapter with background information on main characteristics of area frame surveys and remote sensing, LUCAS current production process and its interaction with auxiliary information are described. A conclusive paragraph gives hints to preparation of next LUCAS survey 2018 and the new elements included.

2. Area frame and remote sensing main characteristics

2.1 Area frame and LUCAS

LUCAS survey is based on an area-frame sampling scheme. Area frame surveys represent a common approach to gather land cover and land use data. In contrast to mapping techniques (e.g. the CORINE Land Cover project), they provide quantitative statistical results with precision indicators attached to them. Based on the visual observation of a sample of geo-referenced points, estimates of the extent of the main land cover/use classes are computed applying nomenclatures, sampling procedures, data collection methods and statistical estimators, which are harmonized at EU level. This approach has the important advantage of creating only minimum disturbance to land owners and farmers, since data are directly collected in the field by surveyors.

Due to the direct observation of the ground, it can deliver a detailed land cover classification (e.g. distinction between different cereals like wheat and rye). Such a detailed classification is technically not yet possible with photo-interpretation approaches. The multiple parameters collected in the field form allow the mapping of the LUCAS point classification to other international standards such as INSPIRE (INfrastructure for SPatial InfoRmation in Europe) and FAO forest. LUCAS is a multipurpose survey platform for agro-environmental information: ad-hoc in- situ additional modules such as transect (linear elements and land cover changes along a 250 meters walk) or soil parameters can be added to the core part. Three types of information are derived from LUCAS surveys: 1) micro-data: land cover, land use and environmental parameters associated with the individual points surveyed, 2) point and landscape photos in the four cardinal directions and 3) statistical tables with aggregated results by land cover and land use at geographical level; these estimates are based on weighted point data.

2.2 Remote sensing and Copernicus

Remote sensing by earth observation satellites enables to observe broad area at a time, for a long period regularly, as earth observation satellites orbit the earth repeatedly and enable us to know the condition without visiting the area. This is particularly useful where we cannot easily go or when a natural disaster occurs. In addition observation by satellites can acquire invisible information like temperature, and has provided new discoveries to the earth environmental study. Quality of aerial photography for producing clear and crisp photographs and at a scale appropriate for the accuracy and resolution required depends on the conditions in which they are taken.

[1] See paragraph 2.2 for details on Copernicus

Satellite interpretation mapping exercises like CORINE land cover (CLC) use the ground-surveyed LUCAS data and the photos of the sample point, crop and landscape taken for the verification of their image interpretation results as all LUCAS points are geo-referenced.

Copernicus is a European system for monitoring the Earth. Data is collected by different sources, including Earth observation satellites and in-situ sensors. The data provides information about six thematic areas: land, marine, atmosphere, climate change, emergency management and security. The land theme is divided into four main components: Global. Pan-European (CLC, High Resolution Layers HRL). Local (Urban Atlas, Riparian zone, Natura 2000) and In-situ (Figure 1).

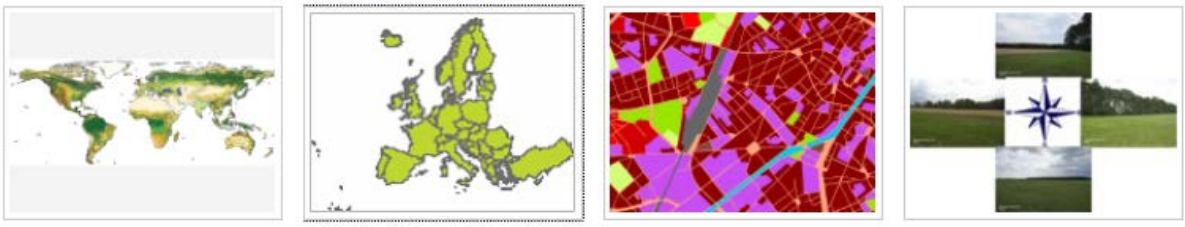

Figure 1 – Copernicus Land components Global. Pan-European. Local. and In-situ (from left).*Source: Copernicus web site*

The pan-European component is coordinated by the European Environment Agency (EEA) and produces satellite image mosaics, land cover / land use (LC/LU) information in the CORINE Land Cover data, and the High Resolution Layers (Figure 2)

Figure 2 – Pan-European products: Image mosaic, CLC and HRL. *Source: Copernicus web site*

CLC is provided for 1990, 2000, 2006 and 2012. This vector-based dataset includes 44 land cover and land use classes. The high-resolution layers (HRL) are raster-based datasets which provides information about different land cover characteristics and is complementary to land-cover mapping (e.g. CORINE) datasets. Five HRLs describe some of the main land cover characteristics: impervious surfaces, forest areas, natural grasslands, wetlands, and permanent water bodies. The High-Resolution Image Mosaic is a seamless pan-European ortho-rectified raster mosaic based on satellite imagery covering 39 countries.

Copernicus land services need both satellite images and in-situ data in order to create reliable products and services. Among in-situ dataset that are considered important for Copernicus Land Monitoring Service, LUCAS data base, in all three components (micro data, photos and statistics), is used for verification of the production results and validation of several information services in the Copernicus Land Monitoring Service portfolio.

2.3 Land cover and land use classification

The two concepts of land cover, biophysical attributes of the earth's surface, and land use, human purpose or intent applied to these attributes are classified separately in the LUCAS survey (Figure 3). Land cover in LUCAS is specified according to a classification with 76 subclasses. At its most basic level: artificial land; cropland; woodland; shrubland; grassland; bare land and lichens/moss; water areas; and wetlands, while land use is specified according to 33 distinct classes that cover the primary sector (for example, agriculture and forestry); the secondary sector (industry); the tertiary sector (services and residential); and other uses (for example unused and abandoned areas).

Figure 3– LUCAS survey Examples of different land cover and land use

Examples of different types of land cover

Examples of different types of land use

Each sampling point has to be classified according to the first and secondary land cover and land use respectively. For example greenhouses according to LUCAS land cover classification are artificial surfaces (A13) with land use agriculture (U110), in other nomenclature they would be defined only as agricultural class.

The 44 classes of CLC classification often mix land cover with land use (Table 1b); this is the case for "Green Urban Areas which are vegetated areas non-agricultural; more linked to a concept of residential use. The tables below show an example of the different classification for artificial surfaces in LUCAS and CLC which are related to "imperviousness" concept defined by Copernicus as the degree of sealed areas. In LUCAS if a point falls on a sealed surface it is coded as artificial (Table 1a) independently from the use; the combination with the land use (table 1c) allows mapping to CLC categories.

Table 1: Imperviousness / artificial surfaces classification in LUCAS and CLC

Table 1 a) - LUCAS

LUCAS land cover classification (selection))			
Level 1	*Level2*	*CODE*	*Level3*
Artificial surfaces	Roofed Built up areas	A11	Building up to 3 floors
		A12	Buildings > 3 floors
		A13	Greenhouses
	Artificial non built up areas	A21	Non-Built-up area
		A22	Non-Built-up linear features
	Other Artificial areas	A30	Other Artificial areas (superimposed)

Table 1 b) - CLC

CLC classification (selection)			
Level 1	**Level2**	**CODE**	**Level3**
Artificial surfaces	Urban fabric	111	Continuous urban fabric
		112	Discontinuous urban fabric
	Industrial, commercial and transport units	121	Industrial or commercial units
		122	Road and rail networks and associated land
		123	Port areas
		124	Airports
	Mine, dump and construction sites	131	Mineral extraction sites
		132	Dump sites
		133	Construction sites
	Artificial, non-agricultural vegetated areas	141	Green urban areas
		142	Sport and leisure facilities

Table 1 c) – LUCAS Land cover artificial classes and allowed combination with land use

LUCAS Artificial land cover		Possible link to LUCAS land use classification	
A11 or A12	Building up to 3 floors or Buildings > 3 floors	U111	Small/tall agricultural buildings, farms, stables, poultry yards
		U120	Small/tall buildings used for forestry purpose
		U130	Small/tall buildings used for fishery production
		U140	Small/tall buildings used for mining and quarrying purposes
		U210	Small/tall buildings used for energy production purposes
		U22x	Small/tall industrial plants and buildings
		U31x	Small/tall buildings used for transport purposes
		U32x	Small/tall buildings used for waste and water treatment
		U330	Small/tall buildings in construction
		U341	Small/tall buildings used for commercial purposes
		U342	Small/tall buildings used for financial, professional and information services
		U350	Small/tall buildings used for community services
		U36X	Small/tall buildings used for recreation
		U370	Individual residential houses
		U410	Abandoned buildings
A13	Greenhouses	U111	Greenhouses used for agricultural production
		U113	Kitchen garden
		U120	Forestry

		U341	Greenhouses used for commercial purposes
		U361	Greenhouses of botanical gardens
		U410	Abandoned greenhouses
A21	Non-Built-up area	U111	Farmyards and parking areas attached to agricultural buildings
		U120	Yards, parking areas attached to buildings used for forestry purpose
		U130	Yards and parking areas attached to buildings used for fishery purpose
		U140	Yards, parking areas, storage areas used for mining, quarrying
		U210	Yards, parking areas, storage areas on industrial sites for energy production
		U22X	Yards, parking areas, storage areas on industrial sites
		U31X	Yards, parking areas, storage areas attached to railway stations, airports, motorways,
		U32X	Yards, parking areas, storage areas attached to installations of waste and
		U330	Yards, parking areas, storage areas attached to installations for construction
		U34X	Parking areas of supermarkets, business, banks,…
		U350	Parking areas of administrations; cemeteries
		U36x	Parking areas of leisure and recreation activities, tennis courts
		U370	Yards and parking areas of residential zones
		U410	Abandoned non built-up area features
A22	Non-Built-up linear features	U31X	U31X Roads, railways, airport runways
A30	Other Artificial areas (superimposed)	U210	U210 Energy production (e.g. a power sub-station)
		U311	U311 Railway transport on a bridge
		U312	U312 Road transport on a viaduct
		U318	U318 Protection works
		U321	U321 Water supply and treatment
		U322	U322 Open dump site (waste treatment)
		U410	U410 Open dump site (abandoned)

3. LUCAS production process: use of auxiliary information

LUCAS survey is based on an area-frame sampling scheme. Its implementation has different steps which involve the use of ancillary information: first a hypothetical grid is laid over the EU territory. The grid nodes are super-imposed over aerial photos and satellite images, with the land cover on these points photo-interpreted and pre-classified ("stratification"). For receiving the necessary detailed classification and avoiding errors due to photo-interpretation, a sample of these points is physically surveyed on the ground. The results, which the surveyors report to the office, are combined with the results of the stratification, for calculating area estimates on the land cover and land use classes all over EU. Next sections give an overview of selected steps of the LUCAS production process.

3.1 First Phase: Base and Master sample

In the first phase the Base sample was obtained using a 1 km-squared grid generated in line with the INSPIRE technical guidelines[2]; it included around 4 350 000 points in the entire European Union territory. The projection used is the Lambert Azimuthal Equal Area (ETRS89-LAEA).

The LUCAS Master sample is a subset of the base sample corresponding to a squared grid, systematic sample with points[3] spaced 2 km in the four cardinal directions covering all EU territory. Each point has been given a unique numeric code going sequentially from South-West to North-East direction.

LUCAS area concept includes NUTS area and Transitional Water. The list included 1 096 510 points spread over 28 EU countries in 2015.

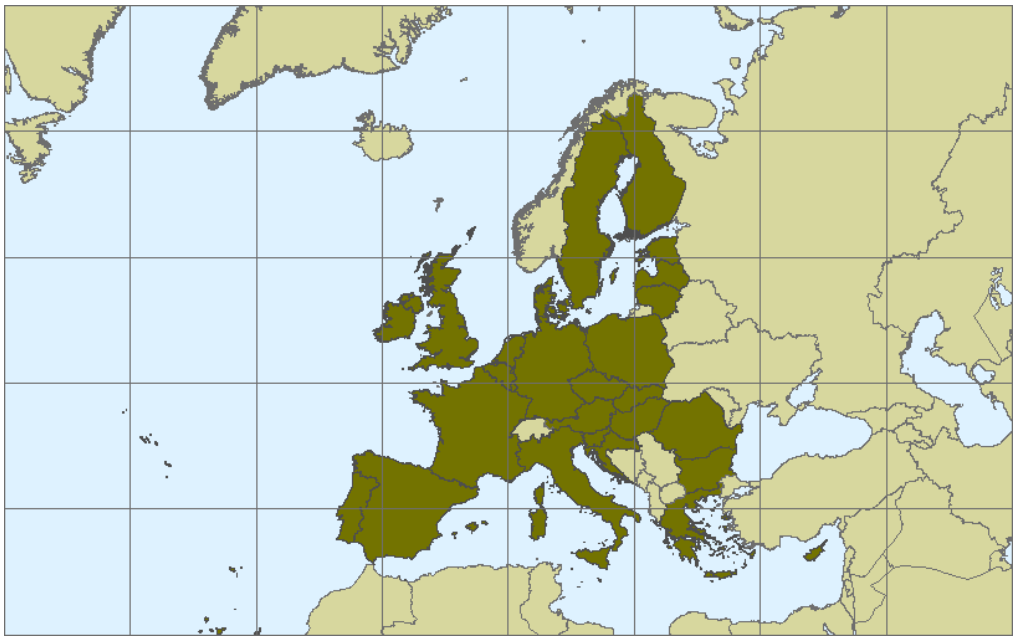

Figure 4 Administrative boundaries: © EuroGeographics © UN-FAO © Turkstat

3.2 Stratification of Master sample

Each point of the master sample is photo-interpreted in order to classify the sample into seven strata ("arable land", "permanent crops", "permanent grassland", "wooded areas, shrubland", "Bare land, low or rare vegetation", "artificial land" and "water"). This photo-interpretation is based on the most recent ortho-photos or, where ortho-photos are not available, on best available satellite imagery with coarser resolutions. The first stratification was carried out in 2006 for a pilot exercise (CORINE Image 2000 Landsat Images); with the years new countries have been added. Results of the stratification are reported in Table 2 and Fig. 5. A new harmonised updated stratification for all 28 countries is planned to start at the end of 2016.

[2] http://inspire.ec.europa.eu/documents/Data_Specifications/INSPIRE_DataSpecification_GG_v3.1.pdf

[3] with origin: 4,321,000 m West of centre point of the projection (52N, 10 E), and 3,210,000 m South of the projection centre point (52N 10E) and orientation: South – North, West – East.

Table 2: Stratification results (2006-2015)

First phase sample		
	Area in %	**NUMBER OF POINTS**
Arable land	26.8	294256
Permanent crops	2.7	29486
Grassland	16.2	177350
Woodland and shrubland	45.0	493531
Bare land	2.0	22024
Artificial land	4.1	44590
Water	3.2	35273

Source : LUCAS

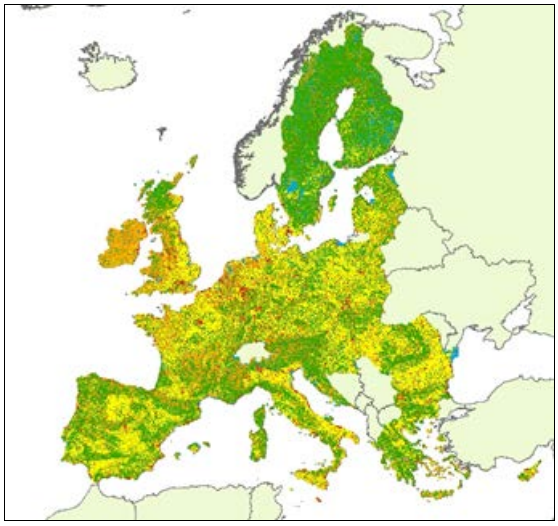

Figure 5: Land cover distribution in 28 EU Member States according to ortho-photo interpretation- ***red = artificial land; yellow = arable ; dark yellow=permanent cropland; green = woodland+shrubland; orange = grassland; brown = bare land; blue = water***. *Source : LUCAS*

3.3 Second Phase

In the second phase a subsample of around ¼ 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 as-signed 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.

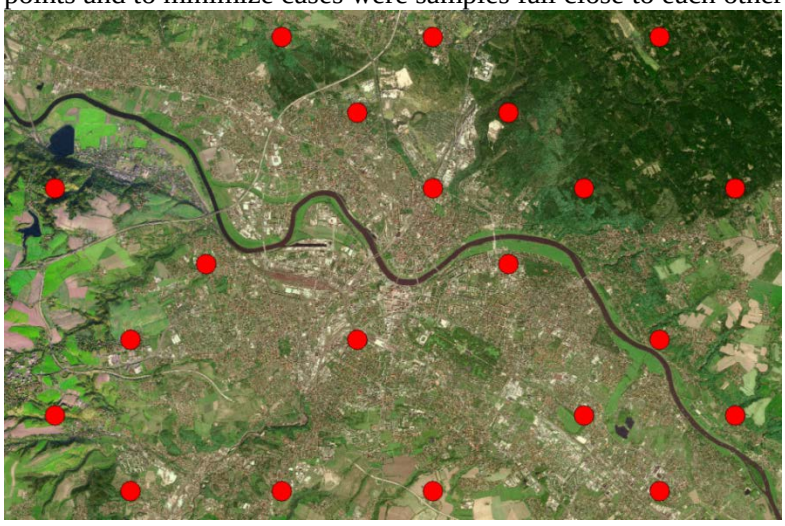

Figure 6 –LUCAS second phase sample examples. *Source ESA Optical VHR2 coverage over EU 2011-2013 ; DWH_MG2b_CORE_03*

3.4 Data collection

The sample unit in LUCAS is a point with observation radius of 1.5 m around the point. If land cover at the point is heterogeneous the observation radius is enlarged to 20 m; this extended window is applied if land cover at the point either belongs to vegetated areas, bare land or wetland.

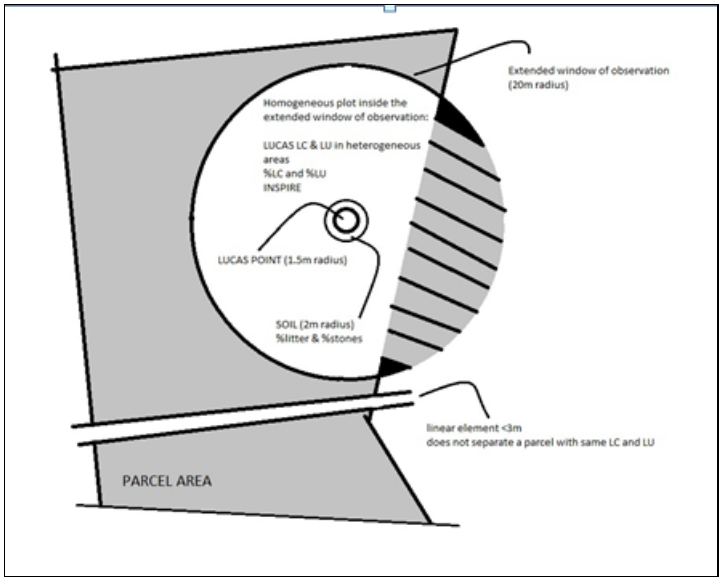

Figure 7 LUCAS 2015 – concept of observation areas *Source: LUCAS Instructions Doc C1*

At each point surveyors go to the points and observe the land cover, land use and environmental parameters they find on the ground. The surveyor documents the land cover and land use according to harmonized classifications. The concept of 'land' is extended to inland water areas (such as lakes, rivers, estuaries or lagoons). The surveyor also collects information relating to the percentage of land cover within a specific window of observation, the area size, the width of any specific features, the height of any trees, as well as information on land and water management (for example, grazing or irrigation). Surveyors receive training before going into the field: they have a set of supporting documents, instructions on how to carry out the survey, and a set of quality control procedures. As such, considerable efforts are made to ensure that each of the surveyors applies the same methods when visiting the assigned geographical point. They fill in a questionnaire with a series of land cover and land use parameters. They also take a series of photographs at each point, of the point itself, as well as pictures in all four cardinal directions (north, south, east and west), before walking 250 meters in an eastwards direction (a 'transect'), recording all of the different land cover and linear elements. These linear features include elements such as walls, hedges, roads, railway lines, irrigation channels or electric power lines.

The information collected for this transect can be used to analyze the fragmentation, richness and diversity of landscapes. A 500 gram topsoil sample is taken at one out of 10 points.

The analysis of the soil samples provided information on soil types, soil textures; pH levels; organic carbon; phosphorous, nitrogen and extractable potassium; soil erosion; susceptibility to compaction. The sample is analysed in a laboratory and used to assess environmental factors, update European soil maps, validate soil models, and measure the quantity of organic carbon in the soil. The surveyors have clear instructions to map and photograph the selected point with a minimum of disturbance and not to cause damage of any kind.

3.5 Ground document

For every sample point a ground document is produced which shows the position of the point and transect line on most recent aerial images (in general below 0.5 resolution) and, if available, additional information from the previous survey (see figure 8). The aerial image supports the surveyor to locate the point and observe the parameters. In case the LUCAS point cannot be reached the surveyor uses the ground document with the aerial image to photo interpret and observe the parameter as detailed as possible from the distance.

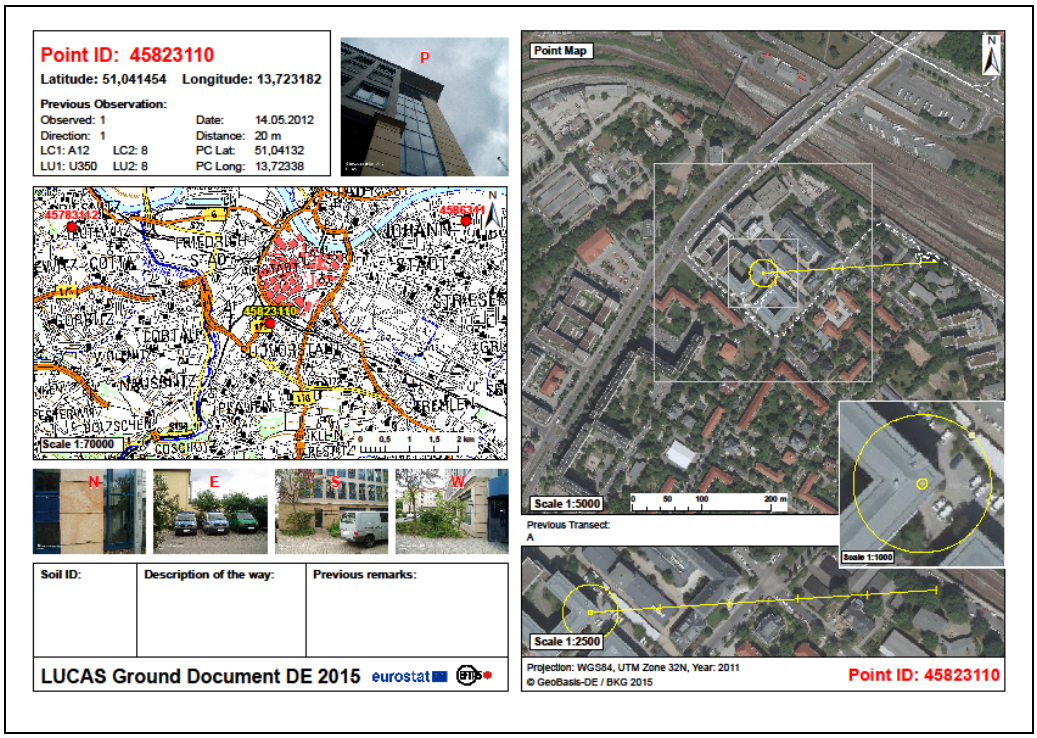

Figure 8 – LUCAS 2015 Example of ground document

Ground documents preparation requires the following geographical products:

- Digital topographic maps with a scale of at least 1:50,000
- Recent (most recently available) suitable licensed or freely available orthophotos or orthorectified very high resolution satellite images to be projected in a scale min. 1:10,000, with an area of a radius of minimum 300 m around the point.

The quality of the orthophotos plays a crucial role as it allows to photointerpret the points with the necessary precision when points are observed from distance or cannot be visited. A ground document has to contain at least the following information: identification of the point, GPS location of the point (latitude and longitude in WGS84), map with the location of the point, orthophoto of the point surroundings, with the location of the point, detail of the orthophoto containing the point location, the observation circle (a circle with 1,5 m radius centered on the point), the extended window of observation (a circle with 20m radius centred on the point) and the LUCAS transect line (a line spanning to 250 m east from the point), photos and data from LUCAS previous surveys.

In the LUCAS data flow several quality control measures are applied including the verification of each point and transect observation using aerial images as well as Google Earth, the photos from the point and information from previous survey, the surveyor uses structured comments to remark if the aerial image is outdated and this supports the use of archive image data for the quality control of the ground survey. Once more the ground documents support the various steps of quality control at all levels. Figure 9 summaries the main steps of LUCAS survey.

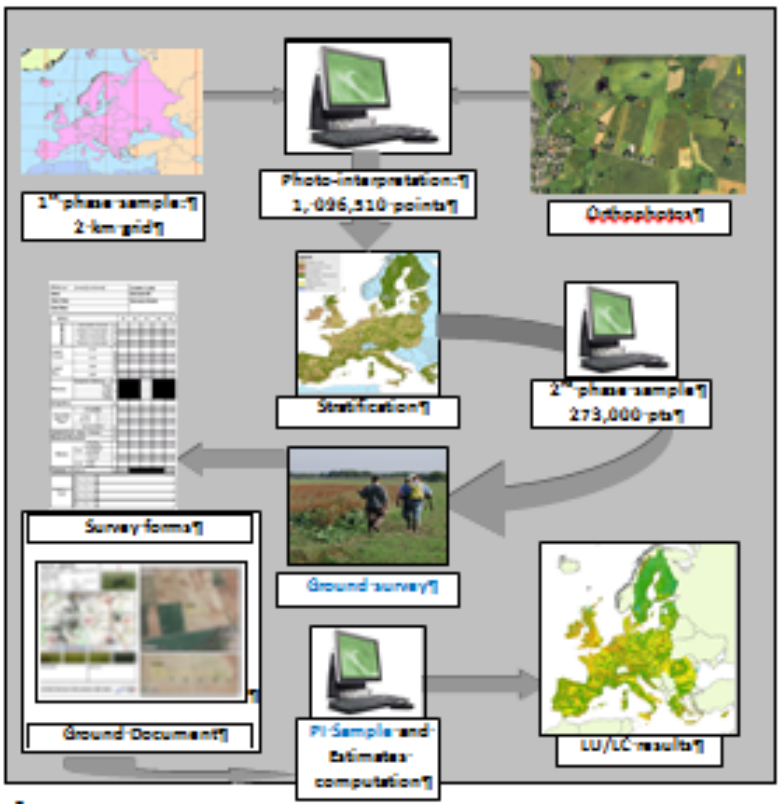

Figure 9: Steps of LUCAS survey

4. LUCAS 2015

The latest LUCAS survey was carried out in 28 EU countries in spring summer 2015 on around 340 000 points, either visited by field surveyors (more than 270 000 points) or photo-interpreted in the office.

For the 2015 sampling exercise Eurostat updated the previous 2-km grid that constitutes the Master sample with most recent auxiliary information; the grid was overlaid with NUTS 2013 GIS layer at the 1:100k scale; those points falling outside the NUTS regions in the NUTS 2013 shape file (Figure 10) were checked and corrected with EEA and national layers of transitional (estuaries, intertidal areas, coastal lagoons) and coastal water; for each point updated values for elevation and distance to the closest road (TomTom) were added to list of attributes. The latest available CLC and HRL classification was added too. The stratification attributes could not be updated for the 2015 survey.

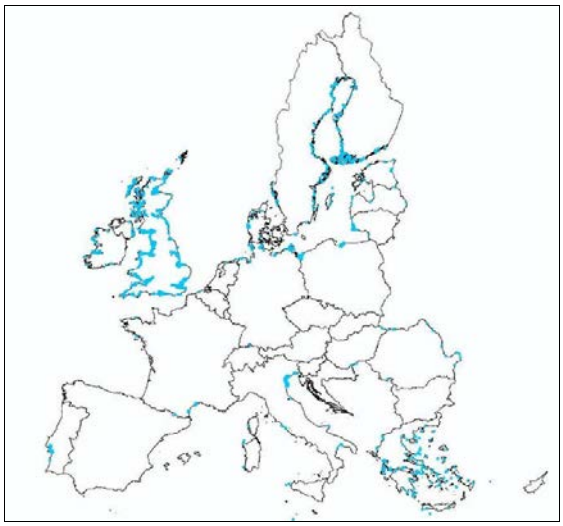

Figure 10. Location of points falling outside the NUTS 2013 boundaries. - *Source : LUCAS*

On the basis of the corrected information of the grid attributes, each point of the Master was classified as eligible or not for field survey. The final eligibility criteria have been defined by combination of elevation, distance to the closest road and accessibility indicators based on CLC. With these rules, the master sample is split into approx. 927 000 eligible points and 166 900 non-eligible points.

The survey design of LUCAS 2015 consists of two samples: a field sample from the accessible areas (273 000) and photo –interpreted sample from the partition of non-eligible (66 000).

4.1 Photo Interpretation in field

Area frame surveys usually foresee people going into the field and colleting in-situ information that are visible on the ground. This could be the case of crops, environmental parameters, forestry features and so on. Since the access to the point can be prevented for many reasons (fences, military areas, wild animals, etc.) it could be that for some units it is impossible to reach the targeted location and assess the land coverage in-situ.

In these situations the recourse to a mixed approach - consisting in the observation of the surroundings of the point combined with ortho-photo interpretation (PI) - is frequently adopted. As a consequence a simplified nomenclature needs to be applied for some land cover categories due to the difficulties in properly distinguishing among specific classes (i.e. durum wheat from oats and barley). In the estimation phase the resulting observations can be considered affected by partial non response phenomenon as some detailed information on land cover might be missing and treated conveniently with statistical techniques.

4.2 Photo Interpretation of excluded areas

The exclusion from target survey population of “difficult to access areas” causes bias in the final estimates; the exclusion of points above certain elevation and difficult to be accessed due to road distance and steepness, becomes critical in particular in mountain areas or remote islands.

Corrective measures for the statistical treatment of the areas excluded from the field survey for accessibility reasons, were identified in an extended sample of points, conveniently selected from the “excluded areas”, to be photo-interpreted with high quality aerial images, is to be added to the original field sample of 273.401 points, and classified according to the LUCAS land cover and land use classification, following the LUCAS methodology. Results of the photo-interpretation part are available together with the field survey in the LUCAS web page.

In synthesis in the LUCAS production process photo interpretation appears three times: 1) during the preparatory phase, for the stratification on the Master grid into 7 land cover classes, 2) during data collection in the field in case the point is not accessible, 3) in the office during the treatment of the

excluded areas. In both cases 2 and 3 the full questionnaire is to be filled with all applicable parameters with the help of ground document information.

4.3 The process

The entire 2015 survey process can be summarized in the following steps (Figure 11):

- Updating/correction of the 2x2 Km Grid [master sample] with recent auxiliary geographical information
- Photo-interpretation and stratification of the points of the master belonging to new countries included in the survey
- Creation of the eligibility indicator for each point of the master sample
- Selection of the field sample from accessible areas
- Selection of the sample to be photo interpreted in the office from non-accessible areas
- Field work in the period March – September 2015
- External Quality control
- First release of point data in July 2016
- After Eurostat validation of the data, combination of macro editing e micro editing activities, final estimates of land cover/use extend will be produced.

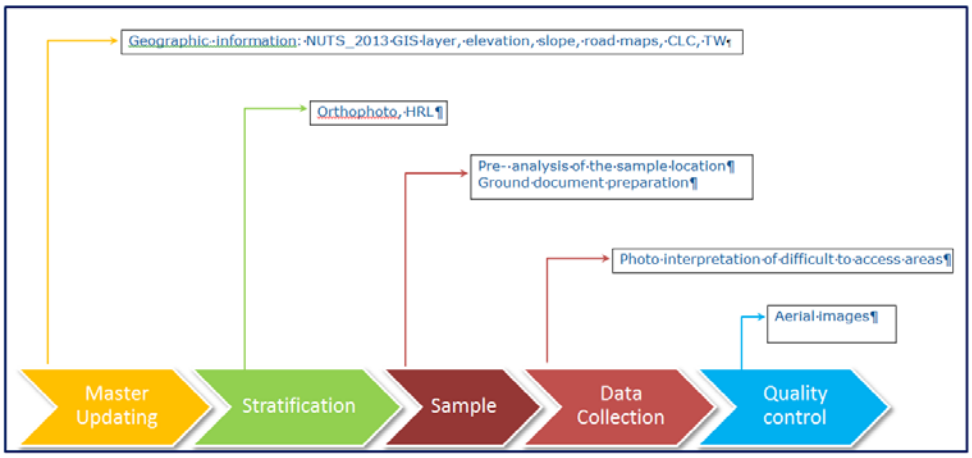

Figure 11 – LUCAS production process – Use of auxiliary information and aerial images

4.4 The output

Three types of information are collected from LUCAS surveys and are freely available in the Eurostat web site: 1) Master sample and Micro-data (land cover, land use and environmental parameters associated with the individual points surveyed) can be downloaded from the LUCAS page, 2) point and landscape photos in the 4 cardinal directions can be visualised in the interactive photo viewer within Eurostat's statistical atlas and 3) statistical tables with aggregated results by land cover and land use at geographical level.

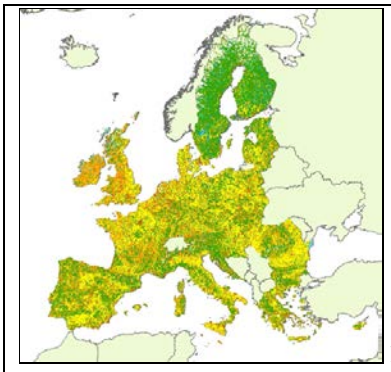

Fig: 12:a In field

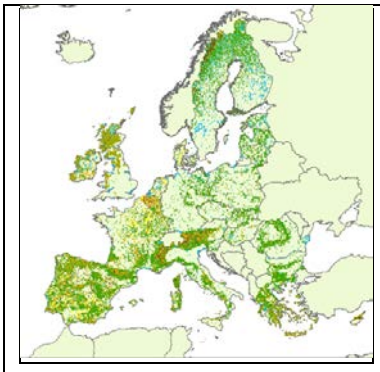

Fig: 12b: PI

Figure 12 shows first unweight results from LUCAS 2015: distribution of main land cover classes in the 2015 field (12 a) and Photo Interpreted (12 b) samples.*[red = artificial land; yellow = cropland; leaf green = woodland; Olive green =shrubland; orange = grassland; brown = bare land; dark blue = water; light blue= wetland].*

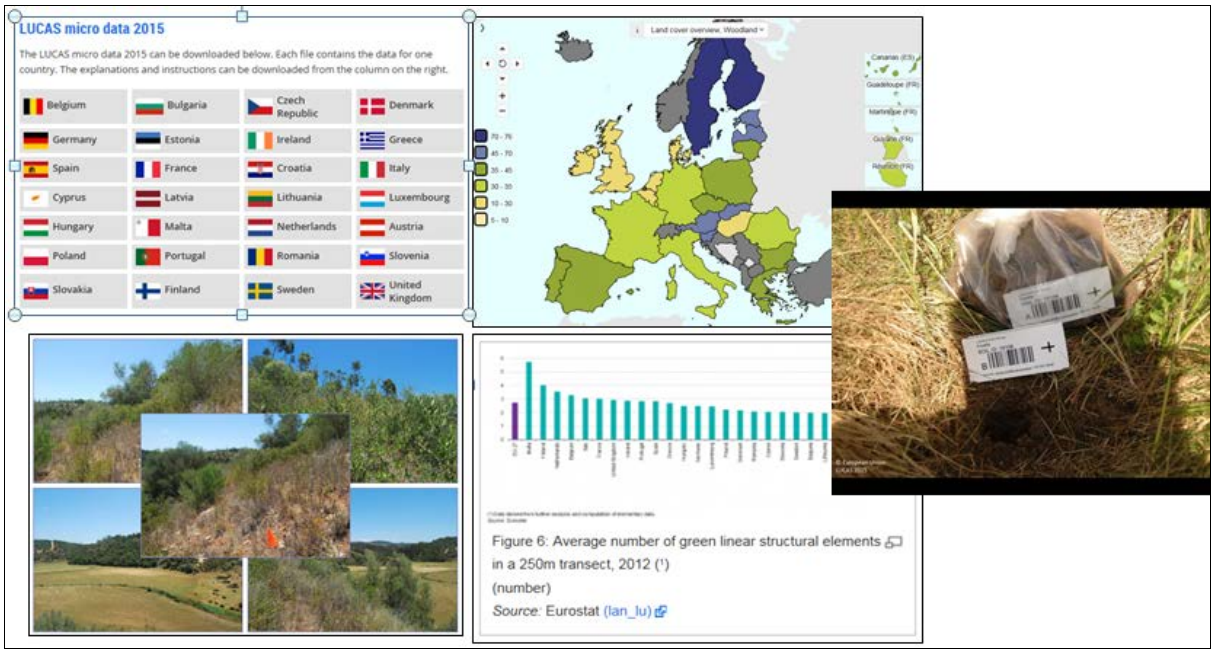

Figure 13 – Examples of LUCAS output

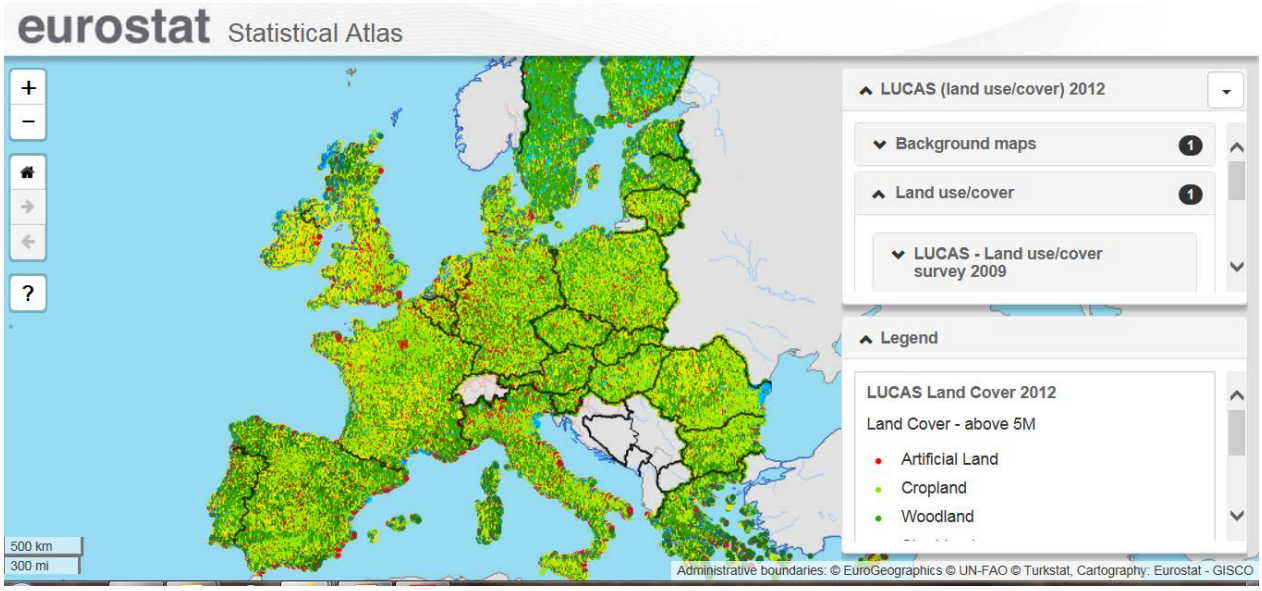

Figure 14 –LUCAS viewer

LUCAS viewer gives access to the elementary data and to the individual photos taken in-situ. The points are classified by the main classes of land cover and land use. By selecting a point, the point's associated information and the photos taken at the point can be viewed. A link to order a larger collection of pictures through an online form is also available.

5. Future work: LUCAS 2018 and the broader picture of the INCA project

Technical preparation for LUCAS survey 2018 started in autumn 2015 and is requiring a tight coordination of the different user needs. A revised stratification of Master sample (LUCAS grid 2 by 2 Km) was launched too. Content wise the survey 2018 includes pilot data collection concerning new topics: 1) a Grassland module on a subsample of points, 2) new Soil[4] Modules developed in tight cooperation with JRC. In addition, some parameters of the core LUCAS are being reviewed to better fit it to Copernicus needs through adapted sampling approaches, nomenclatures. As in 2015 the survey design foresees two samples: a main one for the field visit, a complementary one for the areas excluded to be photo - interpreted. The use of "targeted" photo-interpretation can improve the quality of the final results; it depends on the availability of the images with a corresponding date and evolution. The sampling design could be adapted to better cover the representativeness of some class transitions. Photo-interpretation could be used as pre-assessment of sample unit.

LUCAS will play an important role in the broader EU project[5] on Integrated system for Natural Capital and ecosystem services Accounting (INCA)[6].

The foundation of the system is a common data platform of geo-referenced information on ecosystems and their services, for monitoring and accounting for natural capital. Representative information about natural systems requires a combination of various data sets and layers, including statistics, environmental monitoring data, LUCAS-type ground observation surveys and the analysis of satellite images.

LUCAS data can be used to ground-truth other information and as a basis for models that are used to determine ecosystem condition and ecosystem services. Main contribution of LUCAS comes from the very detailed information related to the specific points which helps to assess to a much better degree the ecosystems conditions available in the broader structured information of a certain surface available through CORINE and from Copernicus maps.

The possibility to characterize the point with several typologies among 250 characteristics[7], photos, soil analysis results and the future grassland species and extended soil parameters, will enhance that potential further towards biodiversity assessment.

6. Conclusion

The paper shows the various interactions between different approaches for land monitoring both from the LUCAS data production process point of view, both concerning the use of LUCAS point information by Copernicus programmes.

Remote sensing technologies and in-situ surveys are complementary; LUCAS and Copernicus programmes are key products on land cover and land use at European level. The generation and purpose of their output products have completely different principles. LUCAS is providing in situ data and statistical land cover and land use information based on a sampling grid. Copernicus is providing land cover and land use coverage maps.

LUCAS is a harmonized EU field survey for land cover and use data collection; LUCAS is a flexible multipurpose platform allowing the collection of specific ad-hoc modules according to policy needs.

The strength of LUCAS is field information; remote sensing can contribute to reduce and optimise the number of points to be visited in the field but cannot substitute the variety of parameters collected within LUCAS survey such as forest, transect, soil or grassland; in addition LUCAS information are taken within one same vegetation period.

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[4] Frozen sample for biodiversity and bulk density

[5] Establishing a sound method of natural capital accounting with a strong focus on ecosystems and their services is a key objective of the 7th Environment Action Programme (EAP) and of the EU Biodiversity Strategy.

[6] The INCA partners consist of Commission Services (Eurostat, DG Environment, DG Research and Innovation, DG Joint Research Centre) and the European Environment Agency.

[7] Including the following typologies: 68 land cover, 33 land use, 85 agricultural species, 14 forest species, 21 transect linear features, 15 water management, plus all indicators derived from other field form parameters

With the new High Resolution (HR) components there is space to further increase the contribution of LUCAS towards Copernicus land monitoring services. Adaptations of LUCAS (e.g. through adapted sampling approaches and nomenclatures) to the programs and their implementation could lead to an improved use by Copernicus land monitoring services.

LUCAS provides a practical example of area frame combing field survey and photo-interpretation of aerial images; for the future the synergies can be optimised to improve the performance of both approaches.

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Useful links

http://ec.europa.eu/eurostat/web/lucas/overview

http://esdac.jrc.ec.europa.eu/

http://land.copernicus.eu/