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The Lucas survey

European statisticians monitor territory

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1. Introduction

Area frame surveys are common approaches to gather land cover and land use data. In contrast to mapping approaches, (e.g. the CORINE Land Cover project[1]) area frame sampling is a statistical method (EUROSTAT 2000). Based on the observation of sample points, area estimates are computed and used as a valid generalisation without studying the entire area under investigation.

To support policy formulation, Eurostat launched - in close co-operation with the Directorate General responsible for Agriculture and the technical support of the Joint Research Centre - the pilot project "Land Use/Cover Area frame statistical Survey (LUCAS)", following the Decision N°1445/2000/EC of the European Parliament and of the Council of the 22.05.2000 "On the application of area-frame survey and remote-sensing techniques to the agricultural statistics for 1999 to 2003".

In 2001, the first LUCAS pilot survey was carried out in 13 of the 15 Member States of the European Union. It had to be postponed to 2002 in the United Kingdom and Republic of Ireland because of the foot and mouth disease[2]. The survey is organized in two phases: a field survey in springtime (phase I) to collect data on land cover/use, as well as on the environment, and a farmer interview survey in autumn (phase II) to gather additional information on yields and agricultural techniques.

Objective of this paper is to describe the aims, the methodology and the first results of the LUCAS phase I survey, presenting a first picture of land cover and land use at the EU level.

[1]Technical guide, available at: http://reports.eea.eu.int/COR0-landcover/en

[2] Due to the foot-and-mouth disease occurred in 2001, it was impossible for the surveyors to move around the countryside.

2. Objectives of the LUCAS survey

The LUCAS survey was carried out in 2001 for the first time, and currently it is still in a pilot phase. The pilot exercise can be seen as having two main purposes:

1. the implementation of the surveys themselves during the years 2001 and 2003, which has provided for 2001 and will provide for 2003 a picture representative at EU level;
2. the detection of changes in land use / cover In fact, besides the picture given in a specific year by LUCAS estimates, one of the strengths of the project is the opportunity it offers to monitor and quantify changes in land cover, land use and landscape structure over time. This temporal comparison is of major importance, first of all thanks to the uniqueness and richness of the information provided, and secondly due to the fact that this information will constitute a precious data source for many other analysis and studies (e.g. the implementation of agri-environmental indicators).

In the above mentioned framework, for the time being only the first part of the pilot exercise has been covered, and there is already evidence and a strong belief that the survey can be seen as a dynamic and efficient approach capable of answering to the following objectives:

- to obtain harmonised information, trying to overcome the lack of tightly harmonised data at European level;
- to represent an extension of a pure land use/land cover information system towards a multi-purpose and multi-user system: the information collected does not only satisfy agricultural statistical users, but also environmental experts who can have at their disposal a homogeneous database for various environmental related questions such as soil erosion, landscape, natural hazards, noise, etc.;
- to offer a common methodology and nomenclature for data collection and computation of estimates, as well as a co-ordinated survey execution, enabling a complete comparability of results between different years and geographical areas once the desired geographical representativity is achieved: a complete set of technical reference documents have been drafted describing e.g. the sampling design, the nomenclature, the observation process, issues of quality assurance and control, data control procedures, reporting and estimation methods;
- to get early estimates of areas that refer to the current year, and the possibility to quantify in real-time the changes with previous situations;
- to provide the statistical information needed for the implementation of indicators to monitor the integration of environmental concerns into the Common Agricultural Policy, as described in the Commission Communications COM2000(20) and COM2001(144): on-going analysis and studies are concerned with the potential of the LUCAS data to satisfy data needs to fill some of the described indicators.

It is important to emphasise that for the time being many of these objectives are not fulfilled regarding the state of land cover statistics at EU level, a domain in which data are often out-of-date, incomplete or not enough harmonised.

3. Methodological implementation

In the following paragraphs the methodology of the survey is reported. For a detailed description of the methods, a set of nine documents was drafted, each one focusing on a specific aspect of the survey. The complete series of Technical Reference Documents is available on the CIRCA Web site[3] of the Commission.

3.1. A two-stage area frame systematic sampling design

Systematic area frame sampling has been chosen as sampling design method, since LUCAS is designed to provide multi-purpose information and therefore needs to cover not only the agriculture area, but all the territory of EU Member States (DELINCÉ 2000, AVIKAINEN & al. 2001).

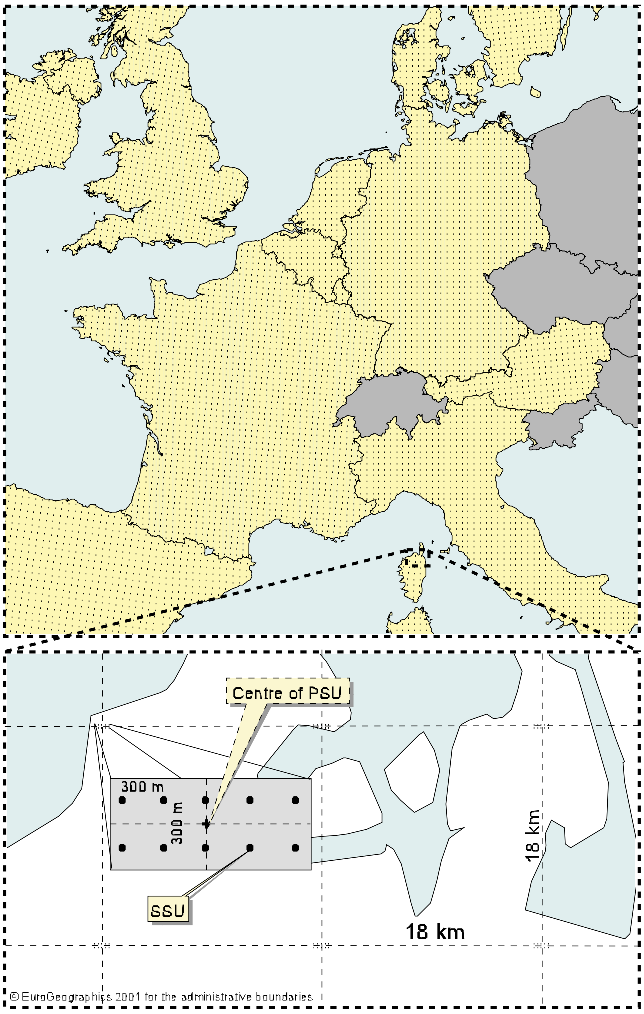


Figure 1: The LUCAS 2-stage sampling

The above described sampling design enables the production of area estimates for land cover/land use categories at the European level; nevertheless interested countries can acquire results at national or regional level by increasing the number of sampled points[4].

The LUCAS phase I survey adopts a two-stage sampling design: at the first level, Primary Sampling Units (PSUs) are defined as cells of a regular grid with a size of 18 × 18 km, while the Secondary Sampling Units (SSUs) are 10 points regularly distributed (in a rectangular of 1500 × 600 m side length[5]) around the centre of each PSU (Figure 1).

The sampling results in approximately 10.000 PSUs over all the EU territory. The number of PSUs was chosen to optimise the cost structure and the precision at European level (Table 1).

Country		Number of PSU	Number of SSU	Area (KM²)	Area in %
Austria	AT	255	2.528	83860	2.59
Belgium	BE	100	989	30520	0.94
Germany	DE	1.105	10.981	356970	11.02
Denmark	DK	147	1.373	43090	1.33
Spain	ES	1.268	12.670	504790	15.58
Finland	FI	1.073	10.410	338150	10.44
France	FR	1.702	16.916	549090	16.95
Greece	GR	419	4.051	131960	4.07
Ireland	IE	218	2.163	70290	2.17
Italy	IT	941	9.275	301280	9.30
Luxembourg	LU	8	80	2570	0.08
The Netherlands	NL	117	1.154	41570	1.28
Portugal	PT	277	2.731	91910	2.84
Sweden	SE	1.407	13.808	449960	13.89
United Kingdom	UK	775	7.499	244150	7.54
EU15		9.812	96.633	3240160	100.00

Table 1: Number of observed PSUs and SSUs per Member State, and surface per country

The observation unit of the LUCAS phase I survey is the point, defined as a circle of 3 m. diameter (Figure 2). Data on land cover, land use as well as environmental features are collected in the field connected with these SSUs. Considering the heterogeneity of land cover types, in some particular cases an enlargement of the observation

[3] http://forum.europa.eu.int/Public/irc/dsis/landstat/library?l=/lucas&vm=detailed&sb=Title

[4] In 2002 this was done in Hungary, in the framework of the LUCAS Phare 2000 programme.

[5] With the exceptions of Spain and Italy, in which the LUCAS sampling plan was slightly adapted to comply with already established area frame systems.

window up to a circle with 20 m. radius is foreseen[6].
Data are collected as well along the straight line that connects the observation points located in the first row (the transects) (Figure 2).

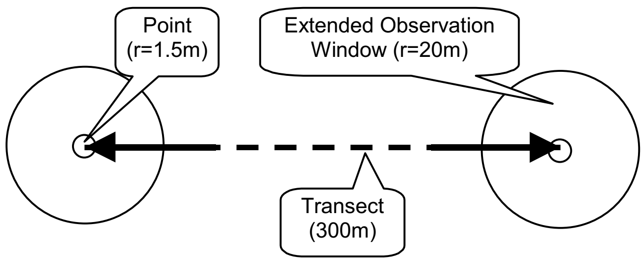


Figure 2: The Point and the Transect

The phase II survey, carried out in autumn, deals with the collection of environmental related information and farming practices. The sample for LUCAS phase II is a sub-sample of about 5750 SSUs (including 15% of reserve) classified in arable land during phase I. The advantage of adopting an area frame sampling strategy relies on the fact that such a kind of sampling does not require an up-to-date and complete list of farms for the sampling. In fact, the location of the selected SSU determines a plot of arable land belonging to a farm, which is then selected and whose manager needs to be identified. Best practice for the identification of the managing farmer is to do it during the phase I survey (ask people met, neighbours, or community administrations).
Observation units of the phase II survey are the agricultural holding itself, and the plot in which the sampled SSU is located.

3.2. A multi-purpose information system

According to the objectives, the survey targets not only the observation of the agricultural domain, but a much wider range of possible land cover types (i.e. built-up areas, forests and wooded lands, bushes and grassland, wetland, water and bare soil areas) and land use categories (residential, industrial, commercial, recreational, etc.); moreover, some environmental-related information is collected.

3.2.1. Land cover and land use information

The LUCAS classification system was established by applying best practise for the construction of land cover and use classifications, as recommended in Eurostat "Manual of Concepts on land use/cover" (Eurostat 2000).
Land Cover is the observed physical cover of the earth's surface, and the Land Use is the description of the same areas in terms of their socio-economic function. The LUCAS concept of "LAND" is extended to inland water areas (lakes, rivers, coastal areas), and it does not embrace uses below the earth's surface (mine deposits, subways, mushroom beds, ground levels of buildings).
The land cover classification is defined in 3 hierarchical levels of detail with 57 classes at the 3rd level, and the land use nomenclature is distinguished in 14 classes at the 3rd level. The complete nomenclature scheme is annexed.

3.2.2. Environmental information

Qualitative information on the existence of infrastructure for irrigation and drainage, as well as data on presence of isolated trees is collected in the field (LUCAS phase I) within an extended observation window of a 20 m. circle around the observation point. Soil erosion and accumulation is also noted when observed in an extended window of observation around SSUs in arable land (land cover classes B1-B6). Traces of Natural Hazards are recorded as well.
Along the transect, the change of land cover and the occurrence of linear features[7] is registered.
Photographs of the landscape are taken at SSU13; these pictures create a photo sample of European landscapes.
The farmers interviews (LUCAS phase II) provides information regarding agricultural techniques (e.g. crop rotation, sowing method, quantities of fertilisers per type, treatment with weed killers, etc.), data on size of areas/plots, yield of crops.

[6] The extended window of observation is applied in the following situations: heterogeneous areas where land features alternate with distances of around 20-25 m.; alternation of permanent crops and bare soils and/or grassland or another crop; crops under cover; wooded and semi-natural areas. The existence of certain features (e.g. isolated trees, soil erosion) is also observed in this extended observation window.

[7] Hedge and tree rows, stonewalls and dykes, water channels, tracks and roads, railways, electric lines.

3.3. Technical implementation of the surveys

The phase I field observation is carried out on the exact geographic location of the sampled SSU, therefore surveyors need to locate very precisely the points to be visited. To this purpose, a set of documents and material were produced and provided them: topographic maps, the most recent and available orthophotos at scales 1:10.000 - 1:2.000, compasses and GPS. A survey form[8] to be filled out in the field was drafted, and adapted to country specific conditions.
The qualification of surveyors is of crucial importance for the quality of the results. Surveyors need skills not only in agriculture and more specifically in crop recognition, but in addition they have to be familiar with the use of supporting tools (maps, orthophotos, compass, GPS). Specific training is organised to this purpose.

As far as phase II survey is concerned, once identified, farmers are contacted by means of a face-to-face, telephone or mail interview. In all the cases, they receive documentation and instructions before the interview.

3.4. Data treatment and estimates

The codification of the collected data was defined together with rules to check data entry and the coherence with the previously recorded information. Data consistency is controlled during data entry at country level; additional integrity controls are carried out centrally by Eurostat.
For the area estimates, LUCAS observations are extrapolated taking into account the characteristics of the 2-stage sampling. The estimates are computed at the level of each item of the classification, multiplying the observed frequency by the total area of the geographical level considered.
Detailed information on the algorithms used to calculate the estimates and the variances is available in the LUCAS technical reference document n.° 9: "Estimation methods" (AVIKAINEN & BERTIN 2001).

3.5. Quality assurance

To guarantee the value of results, quality assurance and control procedures were defined (LUCAS technical reference document n°7: "Quality Assurance and Control procedures", ORESNIK et. al. 2001). In addition, Eurostat guarantees continuous assistance by means of electronic communication to help the partners that carried out the survey in each country.
Supporting the above quality assurance measures, additional internal quality checks are carried out by the survey-managing organisations during the field work, in order to detect and correct eventual misinterpretations or systematic errors. A double-blind control survey is carried out on 5% of the phase I sample to assess the accuracy of the observations.
Eurostat's follow-up of the survey includes the organisation of plenary co-ordination meetings; in addition, bilateral follow-up meetings are planned in each country.

[8] See annex 8.8

4. Realisation of the survey

4.1. Quality of observations

The technical conditions under which sampling points were observed on the ground are fundamental to ensure high quality of results, that depend primarily on two parameters. Firstly, the point location on the ground has to be as precise as possible in order to respect the systematic character of the sampling plan, and to detect correctly the changes that occur in the ground once the survey is carried out periodically. In fact a shift in the exact location of a surveyed point can induce the detection of a change between two consecutive surveys which has not actually occurred.
Secondly, once the point is correctly located the recognition and classification of the ground observations needs to be assessed without ambiguity. This task fall mainly on surveyors, whose profile and training have to be adapted consequently.

4.1.1. Precision of the location

Location of the points on the ground

Three different tools are used to locate the points on the ground:

- aerial (orthorectified) photographs;
- topographic maps;
- compasses and eventually GPS.

These instruments are used in a combined way. The topographic maps (from 1/100 000 to 1/50 000 scale) are used to define the best route to reach PSUs. At the level of SSUs, it is primarily the aerial photographs that are used for a precise location, with the additional support of GPS, compasses, and of large scale topographic maps (1/25 000 to 1/5 000). In order to be correctly located on the ground, the sampling points are preliminary printed on aerial photographs and on large scale topographic maps. Therefore the quality of the aerial photographs is decisive for the orientation of surveyors in the field, and in order to ensure the correct location of the surveyed SSUs.
The survey equipment as described above allow the best transcription of ground reality, once it has a good degree of accuracy.
The quality of aerial photographs is related to two different parameters: its resolution and its positional accuracy. The date of the snapshot is very important as well, in particular in the areas where changes are rapid (i.e. boundaries of urban areas): the landscape grasped on the photograph has to correspond as much as possible to that observed at the time of the survey.
The resolution of a photograph is the area that one image pixel represents on the ground. An object on the ground is in general recognisable on a photograph when its size is 2 to 3 times higher than the ground resolution of the image. This rule is important in particular when the land cover is heterogeneous.

Country	Resolution/ scale	Year of acquisition	Type	Use of GPS
AT	0,5 m	1990/2000	Orthophoto	yes
BE	1 m	1995/2000	Orthophoto	yes
DE	0,25 - 0,8 m	>1995	Orthophoto & aerial photo	yes + DGPS
DK	0,4m	1999	Orthophoto	yes
ES	0,75 - 2 m	1985/2000	Orthophoto & aerial photo	no
FI	1 m	1996	Orthophoto	yes
FR	0,5 - 1 m	>1995	Orthophoto & aerial photo	no
GR	1 m	1990/1998	Orthophoto	yes
IE	1m	1995	Orthophoto	yes
IT	1 m	n.a.	Orthophoto	yes
LU	1/5000	1997	Topogr. map	yes
NL	1m	>1995	Orthophoto	DGPS
PT	1 m	2000	Orthophoto	yes
SE	1 m	>1995	Orthophoto	yes
UK	1m	1988/2001	Orthophoto	yes

Table 2 - Characteristics of aerial photographs used in the 2001 survey

Since the size of the LUCAS observation unit is equal to 3 metres, the resolution does not have to exceed 1 meter in order for the surface type to be easily recognisable on a photograph (figure 3). The photographs used for the 2001 survey had a resolution equal to 1 m in the majority of cases (table 2); the overall quality in terms of resolution of the orthophotos used can therefore be considered satisfactory.
Concerning the positional accuracy of the photos, it depends on the geometrical corrections they have undergone, that defines the precision of the geographical co-ordinates of an image pixel. In the majority of cases, orthophotos were used for the LUCAS survey (table 2). Orthophotos are georeferenced aerial photographs for which corrections were applied in order to take into account distortions due to relief (figure 4).

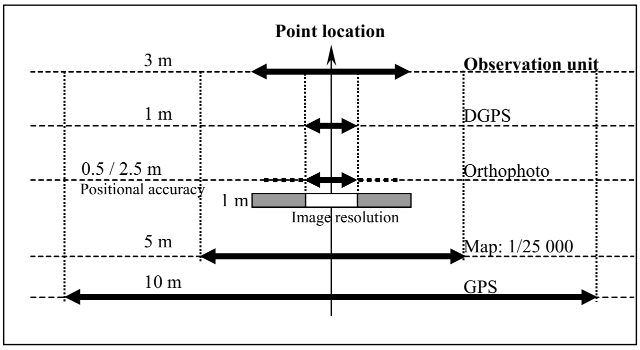


Figure 3 - Precision of the topographical instruments

The positional accuracy of orthophotos depends on the precision of the digital elevation model used to correct the effects due to relief, and on the location precision of the control points used to georeference the image. On the average, this precision varies between 0.5 and 2.5 m.
In a minority of cases, simple aerial photographs (georeferenced but not orthorectified) were used in the 2001 survey; their geometrical quality is lower than the one of orthophotos, since they remain sullied of the errors due to relief distortion[9]. The use of simple photos is acceptable in areas where relief is not accentuated (e.g. plain, plateau).

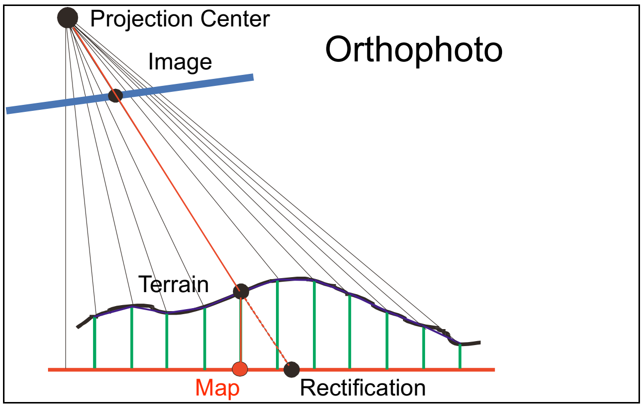
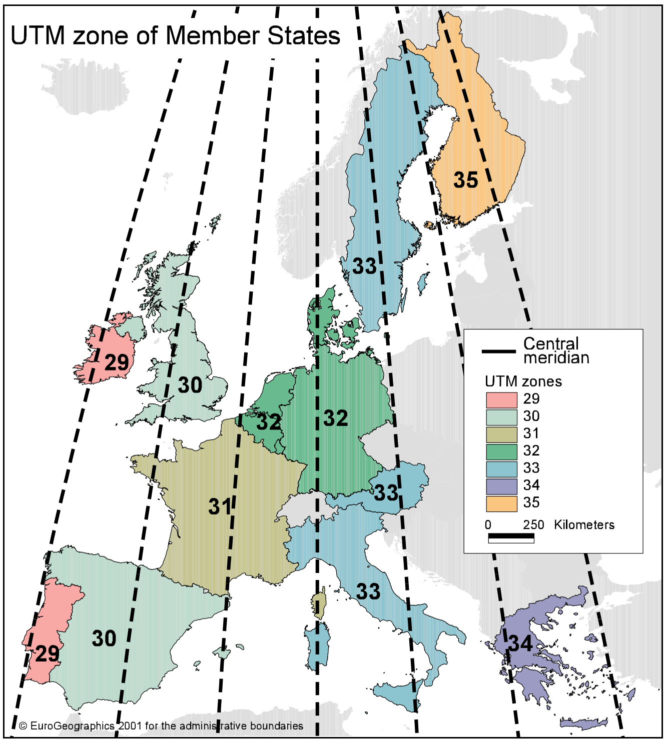


Figure 4 - Scheme of the ortho-rectification process

Location of the points on the photographs

The LUCAS points are referred on the WGS84 ellipsoid, and projected in the UTM system. To limit distortions, the sampling plan was generated in the UTM zone of each country (Map 1).



Map 1 - UTM zone of the Member States

In order to print the LUCAS points on aerial photographs and/or topographic maps, SSUs are projected in the same national geographical system in which topographical documents are referred. A different reference system is used for each country, that consists in a specific ellipsoid (i.e. Datum) and projection system (e.g. Lambert, Mercator). The change of projection system from one country to another, easily operable with map-making software available on the market, induce only few geometrical distortions (lower than 1 m).

4.1.2. Surveyors

The quality of the observations carried out on the ground is essentially the result of surveyors expertise. Surveyors need to be trained in order to develop adequate capacities to use the various topographical instruments, and in order to orientate themselves correctly on the ground. Moreover, they require good capabilities to classify correctly the variables collected according to the classifications developed.

The surveyors profile in the 2001 survey

Table 3 synthesises the profile of surveyors that carried out the 2001 survey.

[9] It is however possible to project the geographical co-ordinates of a SSU on a photo not orthorectified. This method allows to use an unprocessed image which has the advantage to better represent the relief. But its costs would have been prohibitive under the LUCAS project.

Country	Geogr. Envir.	Engineer agronomist forester	Technician agronomist or in agricultural survey	Other	Total number of surveyors	Total number of supervisors
AT	6		1	3	10	1
BE-LU	1	4			5	1
DE	6	1		2	9	2
DK		1		2	3	1
ES			220		220	12
FI	18				18	2
FR			292		292	90
GR		1	5		6	2
IE	4				4	1
IT		23	36	1	60	3
NL		3			3	2
PT		2	3		5	1
SE		2	16	9	27	6
UK			12		12	4
EU15	35	37	585	17	674	128

Table 3 - Surveyors profile in the 2001 survey

They can be classified mainly in 5 profiles:

- geographers/consultants in environment: students or personnel with a diploma in geography and/or specialisation in environment, having in general good knowledge in the geographical data processing field and the manipulation of topographical instruments (GIS, GPS, photo-interpretation, etc.);
- agricultural or forestry engineers: specialists in agricultural and/or forestry sector, previously employed in agricultural surveys. This personnel is experienced because it has been working as permanent staff of the company for several years;
- technicians in agronomy or in agricultural surveys: personnel with various qualifications in the field of agriculture. On the average they have experience in the agricultural field, particularly in the control of the CAP subsidies (IACS), in the field of geographical data processing and manipulation of topographical instruments (GPS, orthophoto, etc.). This category of personnel has been working as permanent staff of the company for several years as well;
- regular surveyors: personnel used regularly by agricultural statistical offices involved in LUCAS-similar surveys (e.g. France, Spain). These surveyors are experienced in the agricultural survey domain (observation on the ground, surveying of farmers);
- other surveyors: personnel with different profiles: biologists, geologists, teachers, drivers.

Mainly specialised personnel was employed in the LUCAS 2001 survey (table 3).

Training and surveyors' supervision

Surveyors followed training courses based on the technical documentation provided by Eurostat, concerning mainly the classification system adopted and the instructions to surveyors. Each surveyor followed at least a one-day training on the ground to tackle practical problems.

In Spain, surveyors did not follow any practical training, due to the fact that they were already familiar and experienced with area frame surveys. However, all the questionnaires they filled in were afterwards checked centrally, comparing the results of the field visit with the ones obtained by the orthophotos analysis.

In France, training was ensured at departmental level by decentralised national services; each surveyor was accompanied by the departmental supervisor for the first 2 or 3 surveyed PSUs.

As a rule, the companies in charge of the project in each Member State were required to survey twice a percentage between 5 and 10% of the SSUs already visited. This double survey was carried out at the beginning of the campaign, in order to check and correct eventual deviations in the interpretation of survey instructions.

4.2. Metadata concerning the 2001 data collection

4.2.1. Period and observation time

On the average, the survey began in May and lasted from 2 to 3 months. In the United Kingdom and Ireland, the data collection of 2001 had to be deferred to 2002 due to the foot-and-mouth epidemic. For similar reasons the survey in the Netherlands started only the 18^{th} of June 2001.

An average of 2 hours was required to visit each PSU; this including just the time necessary to walk for at least 3 km (i.e. 10 x 300 m between each SSU) (table 4). The configuration of the terrain influenced SSUs accessibility, and consequently the time spent for the ground visits varied a lot: from less than two hours in plain areas, to more than 10 hours in steeply sloping ground and/or occupied by a vegetation not easily penetrable.

MS	Surveyors	PSU	PSU/ surveyor	Minutes/ PSU	Month of work	Year
AT	10	255	26	142	1	2001
BE	3	100	33	90	1	2001
DE	9	1105	123	64	3	2001
DK	3	147	49	110	2	2001
ES	220	1267	6	133	3	2001
FI	18	1073	60	93	3	2001
FR	292	1702	6	180	3	2001
GR	6	422	70	99	3	2001
IE	4	218	55	136	2	2002
IT	60	941	16	93	3	2001
LU	2	8	4	125	1	2001
NL	3	117	39	94	1	2001
PT	5	277	55	145	3	2001
SE	27	1407	52	117	3	2001
UK	12	775	65	138	3	2002
EU15	674	9814	15	117	2,3	

Table 4 – 2001 survey's performance

According to the specifications of the survey, SSUs located at more than 2000 m. of altitude were photo-interpreted rather than visited on the ground. It was the case for very isolated points as well, such as those located in the middle of the Scandinavian forest or on islands not served by a regular transport service.

4.2.2. Observation distance

The data collected by photo-interpretation concerned 12% of the total amount of investigated SSUs (figure 5).

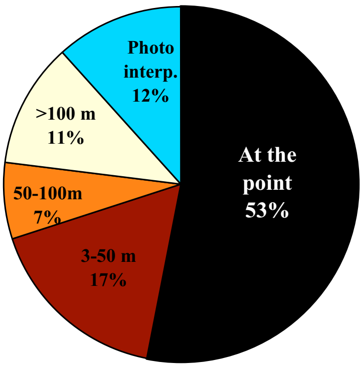


Figure 5 - Distance of observation of the points

88% of the SSU were observed on the ground. According to their accessibility/visibility, it was possible to observe them either directly or within short distance: 70% of the observed points were observed at a distance ranging from 0 to 50 m. More than 80% of the points located in artificial areas had to be approached closely in order to identify the type of cover correctly (figure 6). On the other hand, the land cover of the points located in shrubland was more easily identifiable remotely.

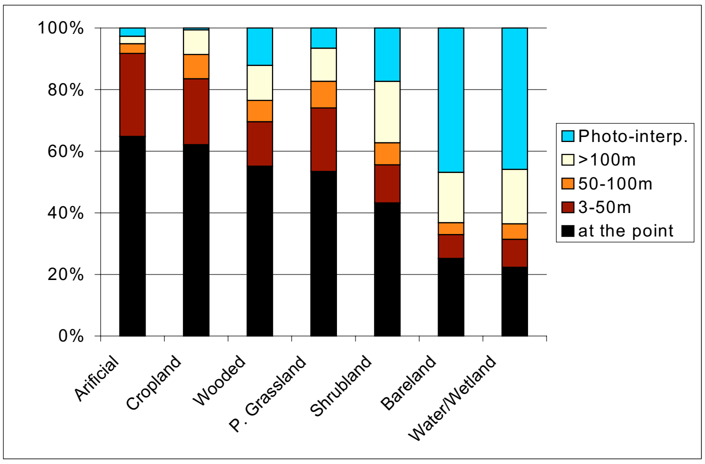


Figure 6 - Observation distance by land cover

The definition of the land cover of the SSUs located on bare land, on inland water bodies or in the wetlands was largely carried out by photo interpretation.

5. Main results of phase I survey at EU 15 level

In the following chapter the main results of phase I survey are presented. In particular, land use, land cover and their cross distribution are analysed; the presence of linear features, the risk of natural hazards and the perception of noise are reported as examples of the environmental variables collected.

The tables of results hereafter reported include the coefficient of variation ($CV = \frac{\sigma}{area}$), which indicates in percentage the achieved precision of each estimate. The specifications of the LUCAS pilot project stipulated to reach a precision of 2% concerning the main land cover classes.

5.1. Land cover

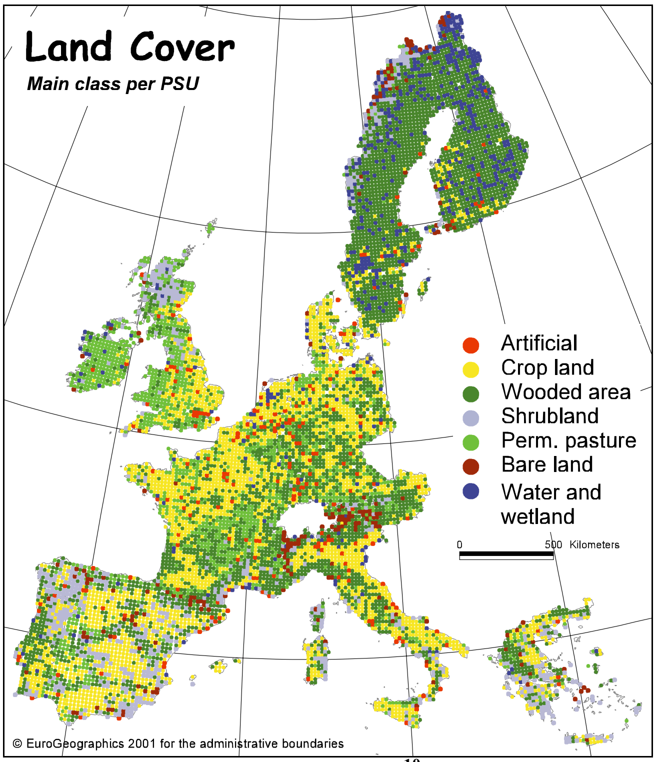
Woodland covers almost 1,2 million km^2, or 35% of the total area of the 15 EU countries concerned by the survey. This makes it the leading type of land cover in 2001. Areas under crops account for 26% of the territory, and grassland for 16%.

Land Cover	KM²	%	CV
Woodland	1.134.606	35,0	1,0
Cropland	837.536	25,8	1,3
Permanent grassland	509.573	15,7	1,4
Shrubland	268.693	8,3	2,9
Water and Wetland	236.111	7,3	3,0
Artificial land	153.912	4,8	2,7
Bare land	99.729	3,1	5,3
Total	3.240.160	100,0	

Table 5 - Land cover estimates

At EU 15 level (table 5), the main type of land cover consists of areas that are entirely or more or less in their natural state. On the other hand, the artificial areas represent only 5% of EU surface (154.000 km^2).

The concentration of wooded areas and of inland water (lakes and wetlands) in the Scandinavian countries is very high, especially when compared to the rest of EU territory (map 2).



Map 2 - Main Land Cover per PSU[10]

The intensive agricultural zones are located in Denmark, eastern part of England, north-western half of France, Po river plain and Adriatic coast in Italy, south of Portugal and Spain.

Shrublands are mainly concentrated in Mediterranean countries, but their presence is noticeable in the north-west border of Sweden and in the highlands in Scotland as well.

[10] Warning: maps report the most represented class for each PSU.

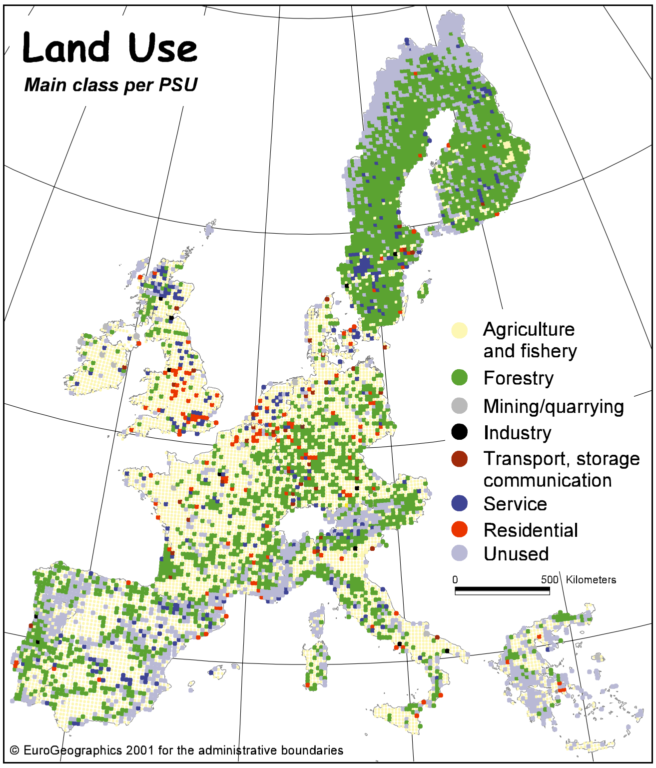
5.2. Land Use

Agriculture accounts for more than 41% of the territory, making it the leading type of land use in the 15 countries investigated (table 6). This category includes land used directly for production as well as land used generally for farming purposes (buildings, farmyards, etc.). Apart from the extreme situations of the Nordic countries and Austria, on the average around half of the territory or more is used for farming.
Forestry comes second, with a percentage of 30%. If this criterion is used, the order of countries is the reverse of farming. In Sweden and Finland, forestry accounts for over half of the territory; in the remaining countries more than 20% of the territory is used for forest purposes (apart from The Netherlands and Denmark).
Almost 19% of the territory of the 15 countries is classified as being without apparent use. The differences are attributable to geographical conditions (altitude in Austria) or type of predominant cover (heath in Portugal and Greece, inland waters in Finland).

These three headings (agriculture, forestry, unused) account for 90% of the territory of the EU15. Of the remaining types of use, only three exceed 1% - (i) recreation, leisure and sport, (ii) residential and (iii) transport and communications.

Land Use	KM²	%	CV
Agriculture	1.343.180	41,5	0,9
Forestry	972.952	30,0	1,2
Unused	603.630	18,6	1,6
Recreation, leisure, sport	131.805	4,1	4,7
Residential	74.584	2,3	4,4
Transport, communication, storage, protective works	65.644	2,0	3,6
Community services	11.745	0,4	16,6
Fishing	9.743	0,3	17,5
Industry, manufacturing	6.861	0,2	16,1
Commerce, finance, business	6.458	0,2	16,3
Mining, quarrying	6.137	0,2	22,4
Construction	2.668	0,1	23,7
Water, waste treatment	2.566	0,1	21,4
Energy production	2.187	0,1	31,8
Total	3.240.160	100,0	

Table 6 - Land Use estimates



Map 3 - Main Land Use per PSU[10]

Agricultural and forestry activities occupy the majority of the EU territory (map 3). The location of the other activities need to be put in relation to the location of artificial areas, with the exception of leisure and sport activities, that are connected with a higher number of land covers (see following paragraph).

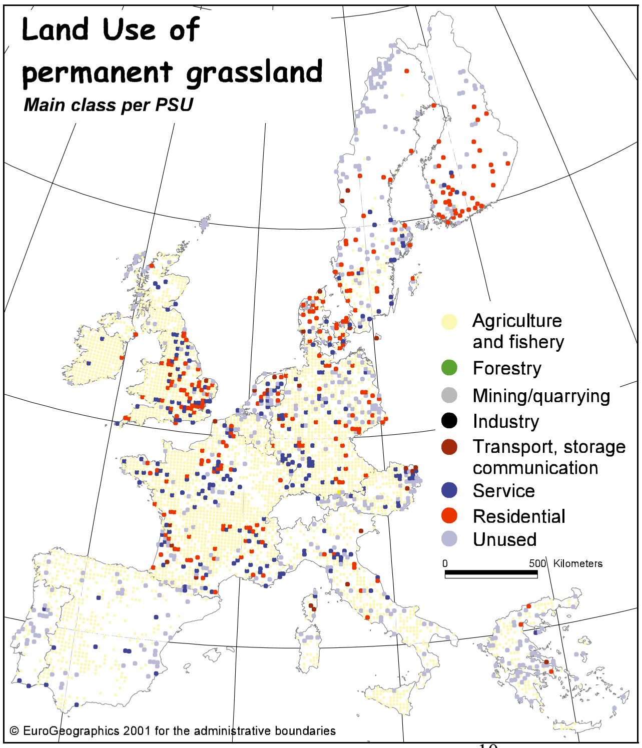
5.3. Mixed land use-land cover

Artificial surfaces show a great diversity of use, two thirds of such areas being accounted for by settlements, transport and communications. At over 10%, agriculture is the third largest user of this type of cover (table 7).

Some 82% of areas under grass are used for agricultural purposes, 9% are unused, residential, leisure and recreation areas account for 8% and the remaining 1% for transport, storage and protective works. The use of areas under grass varies greatly. In Spain, France, Greece and Germany, over 80% of this type of land is used for agriculture. "Other uses" increase from South to North, the trend being for grassland to be used for dwellings (lawns) or recreational purposes (sports grounds). The extreme is Finland, where just 4% of the area under grass is devoted to agriculture and almost 60% to dwellings (map 4).

Cover / Use	Artificial Land	Crop land	Wood land	Shrub land	Perm. Grass land	Bare land	Water and Woodland	Total
Agriculture	0,5	25,7	0,7	1,5	12,9	0,1	0,2	41,5
Forestry	0,1	0,0	29,2	0,7	0,0	0,0	0,0	30,0
Transport, Communication, Storage, Protective works	1,7	0,0	0,0	0,0	0,1	0,0	0,2	2,0
Recreation, leisure, Sport	0,2	0,1	0,9	0,7	0,7	0,2	1,2	4,1
Residential	1,4	0,0	0,2	0,0	0,6	0,0	0,0	2,3
Others	0,6	0,0	0,1	0,0	0,1	0,1	0,5	1,4
No apparent use	0,1	0,0	4,0	5,2	1,4	2,5	5,4	18,6
Total	4,8	25,8	35,0	8,3	15,7	3,1	7,3	100,0

Table 7: Uses of the main covers (%)



Map 4: Main Use of permanent grassland[10]

Shrubland is not generally used (65%). Agriculture accounts for 19% of such type of area, and is the second largest user. Generally speaking, this type of land has a greater utilisation rate in the southern countries (between 20 and 30%). Spain is a special case, as use for forestry exceeds agricultural use.

5.4. *Environmental variables*

One of the objectives of the LUCAS pilot project is to widen the purpose of the survey in the field of environment. The main results concerning three environmental variables are presented hereafter as an example.

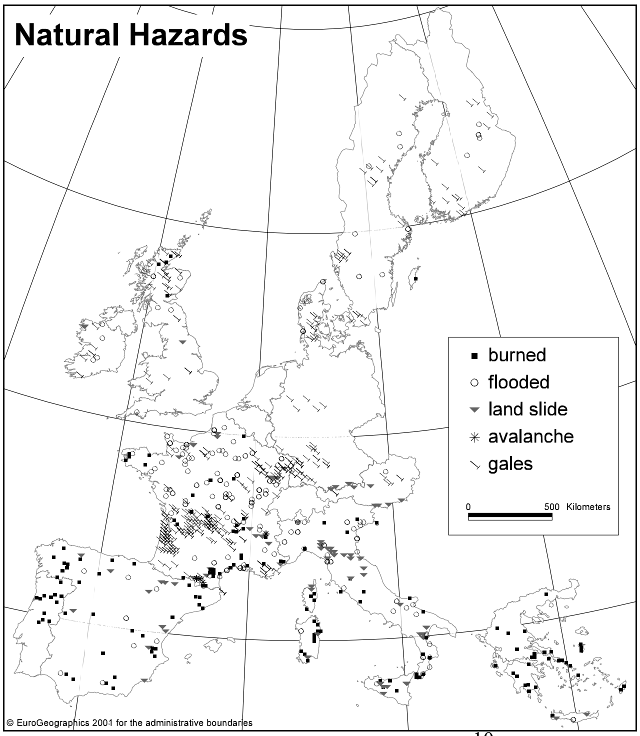
5.4.1. Visible traces of Natural Hazards

Globally, it appears that natural disasters affect 2,7% of the territory of the European Union (table 8). Among them, gales (36,4%) and fires (32,9%) cause most of damages. The right column of the table 8 shows the percentage of each hazard in the total of damaged areas.

Natural Hazard	km²	%	Damaged areas (%)
Avalanche	1.099	0,0	1,4
Land slide	9.635	0,3	10,1
Flooded area	16.756	0,5	19,2
Burned area	29.778	0,9	32,9
Gales	30.519	0,9	36,4
no hazard	3.152.373	97,3	100,0
Total	3.240.160	100,0	

Table 8: Surface of areas affected by natural hazards

The southern countries are affected most, France included, the main cause being fires and gales, accounting both for two thirds of all damages.



Map 5: Visible traces of Natural Hazards[10]

In France, effects of gales are still visible eighteen months after the two storms of December 1999 (map 5).

Table 9 reports the distribution of the natural hazards recorded within each land cover class; the last column of the table reports the contribution of each land cover class in the total of damaged areas. Most of the disasters affects forests (51,4%), shrubland (18,4%) and permanent grassland (10,8%). Most forest damages are the result of gales, accounting for 65,0%, compared with 20,8% for fire damage. Conversely, 81,2% of natural disasters on shrubland are caused by fire while damaged croplands are due for 59,8% to floods (table 9).

Land Cover	Gales	Burned	Flooded	Land slide	Ava-lanche		All Hazards
Woodland	65,0	20,8	5,6	7,8	0,8	100	51,4
Shrubland	3,6	81,2	4,5	8,5	2,2	100	18,4
P. grassland	11,5	29,8	39,7	18,3	0,8	100	10,8
Cropland	1,1	25,3	59,8	13,8	0,0	100	7,2
Water/Wetlan	6,0	3,6	88,0	1,2	1,2	100	6,8
Bare land	3,8	39,6	17,0	30,2	9,4	100	4,4
Artificial	38,5	23,1	30,8	7,7	0,0	100	1,1
							100,0

Table 9: Type of natural hazard by land cover (%)

Focusing on damages caused by gales, the analysis of the covers shows that they involve mainly forest areas, for more than 90% (table 10). Coniferous trees are mostly affected by gales, representing 47% of all damaged land covers.

Gales	%
Coniferous forest	47,3
Broadleaved forest	23,8
Mixed forest	18,8
Permanent grassland	3,4
Shrubland	1,8
Poplar, Eucalyptus	1,4
Other Covers	3,6
	100,0

Table 10: Land covers affected by wind gales (%)

5.4.2. The perception of noise

Noise is one of the variables used to assess the environmental quality of daily life. During their observations, surveyors noted the existence of noise during their stay at the SSU, and classified it according to typology, intensity and origin.
It turns out that according to this subjective observation over 20% of the territory of the 15 countries is considered noise-free, two-thirds has an acceptable level of noise and 10% is classed as having a level of noise that is considered a nuisance.
Noise perception depends on human activity. In countries with a high concentration of human activities (such as the Netherlands and Belgium), the portion of the territory deemed noise-free is virtually non-existent. By contrast, almost three-quarters of Finland is deemed noise-free.
When noise is classified as intensive, road traffic is the main source of disturb, followed by agriculture, forestry and lawn moving (16,4%) and natural noises (wind in the forest, wild animals, running water, etc) in third position, accounting for 10,3% of the sources (table 11).

Noise source	%
Road traffic	58,2
Agriculture, forestry,lawn mowing	16,4
Wild noise	10,3
Air traffic	5,2
Industry	3,7
Rail traffic	3,1
Others	2,2
Human voices	0,8
Total	100,0

Table 11: Intensive noise by source (%)

5.4.3. Linear features

Linear features are important elements of a landscape due to their ecological function as habitats and influence on the human perception (appearance).
In the framework of the LUCAS project, surveyors have to register linear features crossed while walking along the straight line that connects the first five SSUs of each PSU, the so-called transects (Image 1). The number of intersections counted along the transects makes it possible to estimate by extrapolation the length of the linear elements recorded, according to the Buffon's needle theory[11].

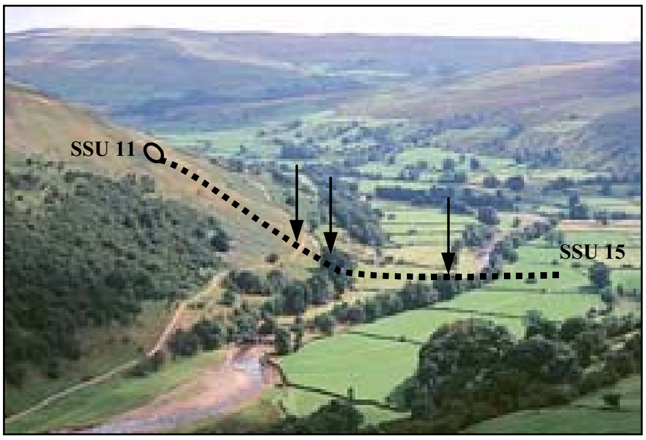


Image 1 - Accounting linear elements along a transect

Figure 7 shows the frequency of the different linear features recorded within the transects. Roads are the most common feature encountered: more than 50% of all transect are dissected by roads, whereby in 30% of all transects more than one road is present. Narrow and large green linear features are important as well, and they constitute quite a distinctive characteristic of the European landscape. The so-called "cultural linear features" (see codification annexed) and railways are quite rare, found in a percentage between 2 and 4% of all the crossed transects.

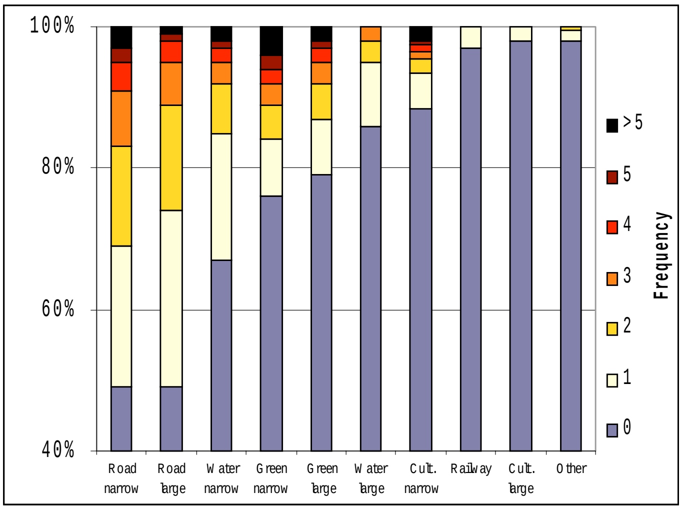


Figure 7: Frequency of the number of linear features per transect (from 0 to more than 5)

[11] Additional information of the Buffon's Needle Problem can be found at: http://www.cut-the-knot.com/fta/Buffon/buffon9.shtml

5.5. Landscape photos

In addition to LUCAS data collection on land cover / land use and some environmental features, it was decided to add photographing of landscape from a systematic observation point for each PSU (SSU n. 13). Surveyors took one photo in each of the four directions North, East, South and West (Image 2); each photo is referenced to the number of the PSU, to preserve its location in space.

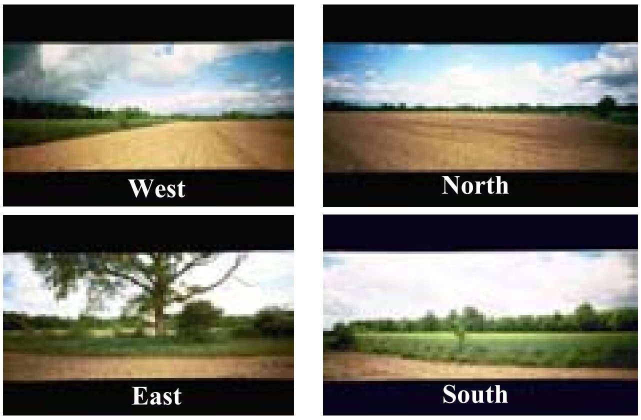


Image 2 – Example of four landscape photos taken in France

20.000 photos approximately were taken in the 2001 data collection. These photos constitute a unique archive of European landscapes, to be exploited with the aim to open new perspectives of landscape analysis, in particular in combination with other sources of information such as aerial photos or satellite images.
The LUCAS pilot project gives therefore a unique opportunity to collect a broad, systematic landscape image material, which will create a base for a new kind and a long term monitoring of landscape changes.

Conclusion

The experience acquired with the LUCAS pilot survey have made it possible to validate the area-frame methodology applied, and the survey has proved its reliability in providing for the first time harmonised and comparable data at EU level.

The summary results reported in this publication show the richness of the data collected up to now. However, the information provided by the survey is far from being fully exploited: LUCAS would impose all its potential once the survey is carried out on a regular and periodic basis, since in this way it would be possible to assess and to locate temporal changes occurring in the EU territory.

Due to its flexible design, LUCAS can be seen as a platform for many kind of applications, especially those related to environmental assessments. Following the Commission communication 2000 (20) stressing the need to develop agri-environmental indicators to support the further integration of environmental concerns into the CAP, Eurostat is studying how to exploit LUCAS data to monitor and evaluate changes in land cover and land use, and their impact on the structure and the diversity of landscapes.

Even if LUCAS results prove to be very promising, the survey has still to demonstrate its strength for gathering relevant data. In particular, additional efforts have to be made to improve the precision of results and the relevance of the observation method adopted.

One of the possibilities to improve the precision of results consists in increasing the density of the sampling plan; additional investigations will be carried out to optimise the sampling design and to find a good balance between the expected estimates precision and its related costs.

The capacity to capture correctly information on land use and on the environment specific of the applied observation method is for some variables still questionable:

- land use is difficult to observe on the ground because it is often multi-temporal: the same area could be used for various purposes in different period of the year. Thus, evidences to certify the presence of a use may require additional information;
- the correct classification of the land use is sometimes possible only if specific actions are met, while not evident at all in standard conditions (e.g. lakes used for fishing purposes);
- moreover, another crucial question concerns the appropriateness of LUCAS for being the correct framework to collect data on environment such as noise and erosion.

All these issues need to be analysed in detail together with the experts from the relevant institutions, in Member States and at international level. This is part of the work program of the LUCAS pilot project in the next years.

6. References

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[12] Available at: http://forum.europa.eu.int/Public/irc/dsis/landstat/library?l=/lucas&vm=detailed&sb=Title

ANNEXES

7. Annex 1: Nomenclature and codification of variables

7.1. Land cover nomenclature

Level 1	Description	Level 2	Description	Level 3	Description
A	ARTIFICIAL LAND	A1	BUILT-UP AREAS	A11	Buildings with 1 to 3 floors
				A12	Buildings with more than 3 floors
				A13	Greenhouses
		A2	ARTIFICIAL NON BUILT-UP AREAS	A21	Non built-up area features
				A22	Non built-up linear features
B	CROPLAND	B1	CEREALS	B11	Common wheat
				B12	Durum Wheat
				B13	Barley
				B14	Rye
				B15	Oats
				B16	Maize
				B17	Rice
				B18	Other cereals
		B2	ROOT CROPS	B21	Potatoes
				B22	Sugar beet
				B23	Other root crops
		B3	NON PERMANENT INDUSTRIAL CROPS	B31	Sunflower
				B32	Rape seeds
				B33	Soya
				B34	Cotton
				B35	Other fibre and oleaginous crops
				B36	Tobacco
				B37	Other non permanent industrial crops
		B4	DRY PULSES, VEGETABLES AND FLOWERS	B41	Dry pulses
				B42	Tomatoes
				B43	Other fresh vegetables
				B44	Floriculture and ornamental plants
		B5	TEMPORARY, ARTIFICIAL PASTURES	B50	Temporary, artificial pastures
		B6	FALLOW LAND	B60	Fallow land
		B7	PERMANENT CROPS: FRUIT TREES, BERRIES	B71	Apple fruit
				B72	Pear fruit
				B73	Cherry fruit
				B74	Nuts trees
				B75	Other fruit trees and berries
				B76	Oranges
				B77	Other citrus fruit
		B8	OTHER PERMANENT CROPS	B81	Olive groves
				B82	Vineyards
				B83	Nurseries
				B84	Permanent industrial crops
C	WOODLAND	C1	FOREST AREA	C11	Broad-leaved forest
				C12	Coniferous forest
				C13	Mixed forest
		C2	OTHER WOODED AREA	C21	Other broad-leaved wooded area
				C22	Other coniferous wooded area
				C23	Other mixed wooded area
		C3	POPLARS, EUCALYPTUS	C30	Poplars, eucalyptus
D	SHRUBLAND			D01	Shrubland with sparse tree cover
				D02	Shrubland without tree cover
E	PERMANENT GRASSLAND			E01	Permanent grassland with sparse tree/shrub cover
				E02	Permanent grassland without tree/shrub cover
F	BARE LAND			F00	Bare land
G	WATER AND WETLAND			G01	Inland water bodies
				G02	Inland running water
				G03	Coastal water bodies
				G04	Wetland
				G05	Glaciers, permanent snow

7.2. Land use nomenclature

Level 1	Level 2	Description	Level 1	Level 2	Description
U1	U11	AGRICULTURE	U3	U32	WATER, WASTE TREATMENT
	U12	FORESTRY		U33	CONSTRUCTION
	U13	FISHING		U34	COMMERCE, FINANCE, BUSINESS
	U14	MINING, QUARRYING		U35	COMMUNITY SERVICES
U2	U21	ENERGY PRODUCTION		U36	RECREATION, LEISURE, SPORT
	U22	INDUSTRY, MANUFACTURING		U37	RESIDENTIAL
U3	U31	TRANSPORT, COMMUNICATION, STORAGE, PROTECTIVE WORKS	U4	U40	UNUSED

7.3. Codification of the variable: "Erosion"

7.3.1. Linear Erosion

Code	Category	Description
-9	No information	Point not accessible
0	No linear erosion existing	
1	≤ 5 rills or gullies	Rills > 5 cm depth, Gullies > 30cm depth
2	6 – 10 rills or gullies	
3	> 10 rills or gullies	

7.3.2. Accumulation

Code	Category	Description
-9	No information	
0	No accumulation visible	
1	Accumulation visible	$< 100\ m^2$
2	Accumulation significant	$> 100\ m^2$

7.4. Codification of the variable "Natural hazards"

Code	Category
-9	No information
1	Burned area
2	Flooded area
3	Area affected by land slide
4	Area affected by avalanches
5	Area affected by gales (wind fall)

7.5. Codification of the variable "Noise"

Code	Source of noise
-9	No information
0	No noise
1	Road traffic
2	Air traffic
3	Rail traffic
4	Industry
5	Agriculture, Forestry,
6	Wild noise (wind, cattle, birds, running water)
7	Human voice (schoolyard, sport activities,..)
8	Others

Level of noise	
1	Quiet
2	Noisy

Type of noise	
1	Continuous
2	Sporadic

7.6. Codification of the variable "linear features" (Transect)

Code	Linear Features	Description
1	Green 1m - 3m	Hedges, rows of trees, baulks
2	Green > 3m	
3	Cultural 1m - 3m	Terrace boundaries, dykes; Walls: Stonewalls are to be considered irrespective of their size!
4	Cultural > 3m	
5	River 1m -3m	Rivers, drainage/irrigation channels or ditches, gullies
6	River > 3m	
7	Electric line	Low/high voltage lines, telephone lines
8	Road 1m - 3m	Roads and tracks including the road sides
9	Road > 3m	
10	Railway-track	
11	Other linear features	e.g. pipelines (water, gas, oil etc.)

7.7. Codification of the variable "land cover transition"(Transect)

Code	LAND COVER
A	Artificial
Ba	Arable Land (B1-B6)
Bp	Permanent crops (B7-B8)
C	Woodland
D	Shrubland
E	Permanent grass
F	Bareland
G	Water and wetland

8. Annex 2: Field form for phase I survey

PSU n° *(row)/(column)*	**Country Code:**
Date:	**Surveyor ID:**
Start Time	**Surveyor Name:**
End Time	

SURVEY ☐

CONTROL ☐

SSU			**11**	**12**	**13**	**14**	**15**
Observation	observed/not observed	a					
	Distance of observation	b					
	Radius of observation	c					
	Direction of observation	d					
Land Cover	**LC1**						
	LC2						
Land Use	**LU1**						
	LU2						
Photos	Snapshot distance	e					
	North	f					
	East						
	South						
	West						
Irrigation		g					
Erosion *(within 20 m radius)*	8= not cropland 9= no information						
	Linear erosion – Rills (depth>5cm)	i					
	Linear erosion – Gullies (depth>30cm)						
	Accumulation	j					
Isolated trees (max. 3 trees)		k					
Natural Hazards		l					
Noise	0= no noise 9= no information						
	Type 1=continuous 2=sporadic						
	Source	o					
	Level 1=quiet 2=noisy						
Farmer *(Phase 2)*		q					

Accepted values

a
0=the point is observed
1=out of the territory
2=forbidden zone
3=marine Sea

b
0=at the point
1=distance 3-50m
2=distance 50-100m
3=distance >100m
4= photointerpreted

c
1=1.5 m (normal)
2=20 m (extended)

d
0=on the point
1=north
2=east

e
0=at the point
1=distance 3-50m
2=distance 50-100m
3=distance >100m

f
1=taken
2=not taken: too dark
3=not taken: no open view

g
0=none
1=exists
8=not cropland
9=no information

r
LINEAR FEATURES:
1=green (1m< <3m) *
2=green (>3m) *
3=cultural (1m< <3m) **
4=cultural (>3m) **
5=water flow (1m< <3m) ***
6=water flow (>3m)***
7=electric line
8=road & track (1m< <3m)
9=road & track (>3m)
10=railway
11= Other linear features

* hedges, rows of trees, baunks.
** stonewalls, terrace boundaries, dykes.
*** rivers, drainage/irrigation channels, ditches, gullies.

i
0= none
1= <=5
2= 6 - 10
3= >10

j
0=no accumulation
1=accum. <100m2
2=accum. >100m2

k
0=abscence
1=presence

l
9=no information
0=no hazard
1=Burned area
2=Flooded area
3=Land slide
4=Avalanche
5=gales (windfall)

o
1=Road traffic
2=Air traffic
3=Rail traffic
4=Industry
5=Agriculture, forestry, lawn mowing
6=Wild noise
7=Human voices
8=Others

q
8=not arable land
0=not identified
1=identified in field
2=identified admin. source

s
LAND COVER transition:
A=artificial
Ba=arable land (B1 to B6)
Bp=perm. crops (B7 + B8)
C=woodland
D=shrubland
E=permanent grass
F=bareland
G=water & wetland

TRANSECT (r,s)		
	From 11 to 12	
	From 12 to 13	
	From 13 to 14	
	From 14 to 15	

Remarks:

Page 1/2

PSU n° *(row)/(column)*

SSU			21	22	23	24	25
Observation	observed/not observed	a					
	Distance of observation	b					
	Radius of observation	c					
	Direction of observation	d					
Land Cover	LC1	e					
	LC2						
Land Use	LU1						
	LU2						
Farmer *(Phase 2)*		q					

Accepted values

Values	
0=the point is observed 1=out of the territory 2=forbidden zone 3=marine Sea	a
0=at the point 1= distance 3-50m 2=distance 50-100m 3=distance >100m 4= photointerpreted	b
1=1.5 m (normal) 2=20 m (extended)	c
0=on the point 1=north 2=east	d
see nomenclature	e

Farmer Identification

SSU			
SSU 11	Firstname	Lastname	Telephone
	Address	Commune	Postal Code
SSU 15	Firstname	Lastname	Telephone
	Address	Commune	Postal Code
SSU 23	Firstname	Lastname	Telephone
	Address	Commune	Postal Code

Remarks (cont.):

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