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Land Cover Classification for Land Cover Accounting

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Land cover is an image reflecting at the same time land use (housing, agriculture, industrial activities, transport, forestry, tourism, nature protection...) and ecosystems (from biomes to species' habitats). It has accordingly a particular role in economic-environmental analysis. This role has been enhanced by the development of GIS tools and datasets which allow producing statistics at different scales and then capture the interactions (long trends, hotspots) across landscapes shaped by geography and history.

GLCN LAND COVER & LAND USE DEFINITIONS¹:

LAND COVER: is the observed (bio)physical cover on the earth's surface

LAND USE: is considered as the arrangements, activities and inputs people undertake in a certain land type to produce, change or maintain it.

The strict theoretical distinction between land use and land cover is important but more blurry in implementation. While uses of land are generally multiple in a single place, one land cover type can be established, although classification may vary – to some extent – according to the attributes chosen or seasonal variability. Often, land use is deduced from land cover (e.g. crop assessment from surface*yield). Often land cover is shaped from land use (e.g. a vegetated area with a city is generally considered as an urban park and not an agriculture area). Therefore the distinction between land use and land cover should not be addressed in too much abstract terms but instead on the basis of purposes and availability of data.

¹ *Land Cover vs. Land Use*, Antonio Di Gregorio, FAO – Global Land Cover Network, Global Land Use Data Workshop, Vienna 22 – 23 May 2008

Land cover change

As such, land cover changes reflect the consumption of land (more or less a finite stock) of a given type and the formation of another type resulting from the use of land and from natural drivers (e.g. climate), sometimes in combination (e.g. desertification resulting from overgrazing in arid areas). Observation and analysis of land cover changes is therefore fundamental information used for a wide range of purposes from urban and land planning to agriculture management, forestry, or water management. At the macro scale, changes in land cover reflect a small number of basic processes such as:

- Dense and diffuse urban extension (sprawl) over agriculture and natural land
- Urban land restructuring
- Extension of agriculture over natural land (deforestation, drainage of wetlands, cultivation of marginal land)
- Intensification of agriculture resulting in internal conversion from pasture and mosaics to arable land
- Crop rotations
- Withdrawal of farming
- Deforestation (when forest is replaced by another land cover type)
- Forest rotations with felling and replantation
- Extension of water bodies
- Changes in natural land cover due to natural or multiple causes
- ...

This list corresponds to the main flows of land cover accounts implemented at the European Environment Agency² for Europe. This land cover flows classification has been implemented in Burkina-Faso with no particular difficulties³. The land cover change analyses done by FAO-UNEP's Global Land Cover Network present a very similar vision, as it can be seen in the case of Kenya⁴, below.

From KENYA: Land Cover Change Analysis 1970-1990-2000, GLCN

“Land cover is subject to dynamics driven by anthropogenic and natural alterations:

- climate-related change (long- and short term)
- burning / fire activities
- cutting and clearing of forests (deforestation)
- grazing activities (intensification of rangelands)
- agricultural encroachments (farming activities)
- fuel wood consumption
- urban expansions (urbanization)
- natural successional processes and regeneration”

² LEAC, EEA Report 11, 2006

³ *Evolution de l'Occupation des Terres entre 1992 et 2002 au Burkina Faso*, Ministère de l'Agriculture de l'Hydraulique et des Ressources Halieutiques, Ouagadougou, Septembre 2006

⁴ http://www.glcn.org/databases/ke_change_en.jsp

Classification of land cover and data sources

Land cover is always identified from an analysis where classification principles are confronted to the reality. “... *defining geographic information classes implies an arbitrary drawing of boundaries in a continuum.*” (Di Gregorio, 2008).

- Cartographic sources:

There are three types of cartographic sources relevant to land cover assessment: earth observation, topographic mapping and administrative data.

Earth observation by aerial photographs or satellite imagery results in two different types of classification methodologies: visual photo-interpretation of landscape features and automatic classification of pixels. In the first case, objects are mapped and labelled. In the second case, pixels radiometry is correlated with in situ observation of land cover types. Note that recent software packages process object-oriented image classification which leads to results very similar to visual photo-interpretation.

Topographic (small scale) maps are for part derived from aerial photographs and satellite images; in addition, they are supported by field observations (ground check).

Generalizing modern topographic databases is a possible way for producing land cover maps at medium resolution. Done in an object-oriented methodology, it delivers results compatible to visual photo-interpretation.

Administrative data on land cover are provided by the cadastre and by administrative maps (urban and land planning, roads, rivers...).

- Statistical sources:

They are three basic types of statistical sources: the administrative data mentioned previously, agriculture censuses and area sampling surveys.

The use of administrative data for land cover is an efficient source in countries with tradition of a regular update of cadastre data. It's is a more difficult source to use when cadastre data are updated only when transactions take place – a common case.

Agriculture censuses generally combine cartography and field surveys. They are rich and very valuable baseline inventories.

Various methods exist for area sampling surveys. They generally rely on grids which are sampled with or without preliminary stratification. They are generally targeted to agriculture and forestry purposes but they cover often other environmental themes.

The purpose of this incomplete description is not to assess a broad and well known area but to emphasize that:

- In the case of land cover, accounting units are defined in a way which is not independent from observation procedures and purpose of the analysis.

- The multiplicity of data acquisition techniques and observation purposes makes it difficult to harmonize data (*see the box below on the situation in Europe*).
- A limited international standardization is possible and required. It could support a modular system into which other sources could be implemented on purpose for fulfilling demands for more details⁵.
- At the international level, the abundance of available satellite imagery indicates clearly the way to follow. At the national level, more detailed Earth observation based maps may have to be combined with or supported by other information sources.

“In the OECD/Eurostat Joint Questionnaire, the land use part had to be temporarily withdrawn in 2008 since the response rate was only 11 % in 2006. 13 Member States sent no land use data at all; most of the others did not send all required details. The main reasons for the low response rate were the total or partial lack of data compatible with the required nomenclature, and the difficulties in reaching data coherence within the same country.” (draft note, Eurostat, 2009)

Land cover classification: bottom-up vs. top-down

There are two international land cover classification systems, the FAO/UNEP/GLCN so-called LCCS and Corine Land Cover (CLC) of the European Union. Although developed on different grounds, they have come with time and experience to remarkably similar practical solutions (legends, nomenclatures) for mapping land cover at medium scales.

The objectives of LCCS can be summarized by this sentence from the introduction of the Land Cover Classification System Manual⁶: *“The approach developed for land cover could serve as the basis for a reference classification system with links to specific expertise, because it describes and allows correlation of land cover with a set of independent diagnostic criteria, the so-called classifiers, rather than being nomenclature based.”* They are reflected in the distinction between “classification” and “legend” (statisticians tell “nomenclature”).

1.2 CLASSIFICATION AND LEGEND

Classification is an abstract representation of the situation in the field using well-defined diagnostic criteria: the classifiers (Figures 1 and 2). Sokal (1974) defined it as: "the ordering or arrangement of objects into groups or sets on the basis of their relationships." A classification describes the systematic framework with the names of the classes and the criteria used to distinguish them, and the relation between classes. Classification thus necessarily involves definition of class boundaries that should be clear, precise, possibly

⁵ *Landscape indicators from ecological area sampling in Germany*, Regina Hoffmann-Kroll, Dieter Schäfer, Steffen Seibel, in *Agriculture, Ecosystems and Environment* 98 (2003) 363–370/2003, Elsevier Science B.V. doi:10.1016/S0167-8809(03)00096-3

⁶ Land Cover Classification System (LCCS): Classification Concepts and User Manual FOR SOFTWARE **VERSION 1.0** - Antonio Di Gregorio & Louisa J.M. Jansen, FAO, 2000, <http://www.fao.org/docrep/003/x0596e/x0596e00.htm>

quantitative, and based upon objective criteria.

A classification should therefore be:

- *Scale independent*, meaning that the classes at all levels of the system should be applicable at any scale or level of detail; and
- *Source independent*, implying that it is independent of the means used to collect information, whether satellite imagery, aerial photography, field survey or some combination of them is used.

A *legend* is the application of a classification in a specific area using a defined mapping scale and specific data set (Figure 3). Therefore a legend may contain only a proportion, or sub-set, of all possible classes of the classification. Thus, a legend is:

- *Scale and cartographic representation dependent* (e.g., occurrence of mixed mapping units if the elements composing this unit are too small to be delineated independently); and
- *Data and mapping methodology dependent* (e.g., an aerial photograph shows different features compared to a satellite false colour composite image).

Classification is used in LCCS with a very precise sense as the process into which you define, identify and organize classifiers. This process is supported by a software. The methodology allows anyone to start building up a classification from the field and come to a result consistent with the general principles, if not with standard categories. This standard legend is limited to the so-called dichotomous phase which distinguishes 8 categories on the basis of 3 criteria: vegetated vs. non-vegetated, terrestrial vs. flooded and artificial/managed vs. natural/semi-natural. Beyond the top level, the identification of the classifiers is guided by the software. Finally a legend can be elaborated by combining classifiers in a flexible way while keeping the consistency with the general principles. This allows better comparisons of subclasses (e.g. of different forests, agriculture patterns...).

Corine Land Cover was created at the time of early reflections on LCCS and doesn't refer explicitly to its concepts. However, many similarities can be observed. Both systems are hierarchical and their higher levels are very similar. Both systems make a difference between the "classifiers" and the final legend. In the case of Corine, it results not from a theoretical position but from an empirical approach of the classification of satellite images by photo-interpretation. In this approach, the landscape units mapped are made of a more or less homogenous cluster of pixels. In other term each pixel is interpreted according to 2 "classifiers": its radiometry (its colour on the composite satellite image) and its position in a broader set. A small "green" area within a urban area will accordingly be labelled "green urban area" and not "pasture" or "forest". An entangled mix of agriculture and natural land will be in Corine just classified as mixed class of a certain type. Instead of being given a set of logical rules (and a software for implementing them), Corine photo-interpreters are supported in their work by extensive guidelines with examples of particular cases in order to ensure the best standardization.

Gaps between Corine legend and LCCS classification rules have been scrutinized in detail. The conclusion is that an automatic translation from Corine to LCCS doesn't

seem feasible at the most detailed level, but “*CLC has potential of interoperability with global land cover activities, e.g. using the 2nd-level classes, aggregating several classes into a single one or also splitting specific single classes*”⁷.

When coming to concrete mapping, CLC can however be considered has a LCCS version for Europe. In fact, in their translation Herold et al. consider LCCS classifiers and CLC empirical classes (the best of what can be extracted from satellite images in a consistent way all over Europe). As a consequence, so-called mixed classes are criticized in theory for hosting several classifiers each. Gaps would have certainly being much smaller if CLC would have been compared to a similar photo-interpretation done with a LCCS legend. In that case, mixed zones are unavoidable and deliver in addition useful information form a landscape perspective.

One can notice that the most interesting products of the FAO Africover project have been produced by photo-interpretation and deliver products very similar to Corine – at least considering so-called “level 2”, circa 15 land cover types. Of course, when going to details, differences take place, not only because of methodologies but because of objects and purposes.

The European landscape is historically very fragmented and a nomenclature for Europe has to take stock of that. Europe’s landscape is as well more artificial and Corine makes an effort for accounting for the detail of residential and non residential artificial land (10 classes instead of 1).

As well, Corine is developed⁸ for supporting first European policies which means that it is highly standardised for comparability reasons. This makes in practice a difference with the implementation of LCCS where flexibility is set as a basic principle. In theory, once classifiers are produced, any legend can be derived but examples of multiple land cover maps from the single production chain remain rare and contingent differences remain between various legends.

A last argument relates to mapping change itself which is also addressed in the same way in Corine and Africover: both surveys are based on the comparison of existing land cover map with more recent satellite images – not on the differences between two vector maps or on the subtraction of pixels, both solutions where noise would be more important than the information itself.

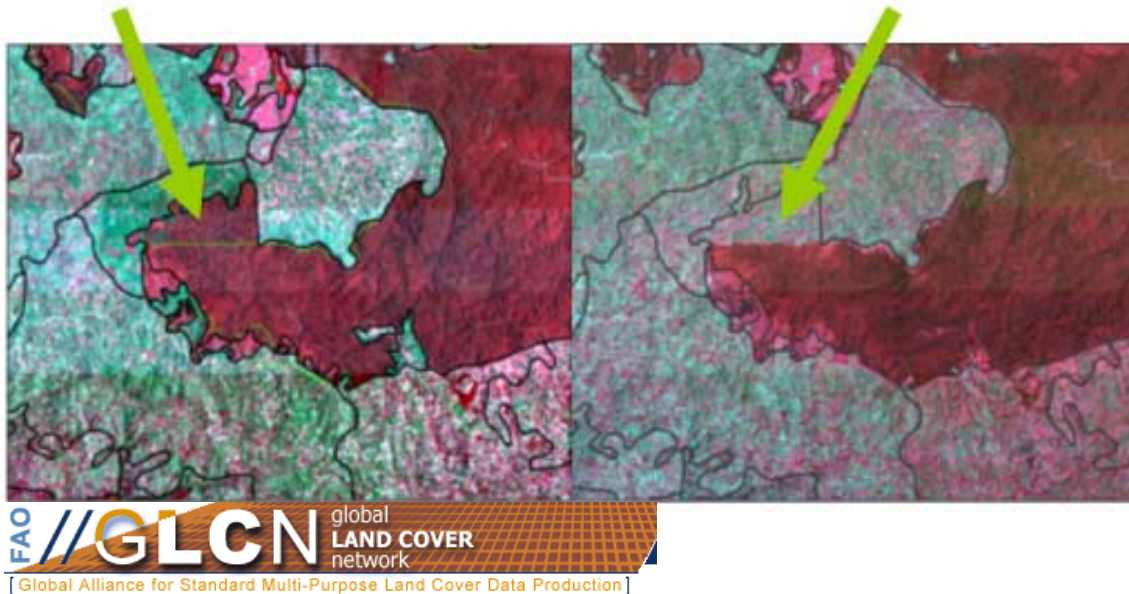
All in all however, when implemented at the 1/100 000 scale by photo-interpretation the two methodologies lead to very similar results at the level of detail which matters for accounting for change. This convergence on practical methodologies is certainly a

⁷ *Translating and evaluating the CORINE legend using the UN Land Cover Classification System (LCCS)*, M. Herold, R. Hubald, P. Sarfatti, and A. Di Gregorio,

⁸ Corine is a joint venture between the European Commission and the 35 EEA member countries (of which the 27 EU member States). The budget is shared, satellite images acquisition and pre-processing is done centrally, photo-interpretation is done by countries. The EEA steers the whole process, including training of national teams, quality control and final data integration into a seamless European digital map.

consequence of the experience gained and gives some confidence in the possibility of a common solution. This solution consists, on the one hand in a limited increase of standardised classes – necessary for international accounting – reducing the degrees of freedom in LCCS classification (beyond the 8 so-called dichotomous classes) and, on the other hand reorganising Corine legend according to possibilities of classification at the global scale (e.g. by grouping pasture and natural grassland).

It is possible to monitor changes in the land cover using remote sensed products (see example below, Kenya, Landsat 1990/2000) where the detection of changes can be highlighted using time series of satellite images.



The particular case of automatic classification of pixels

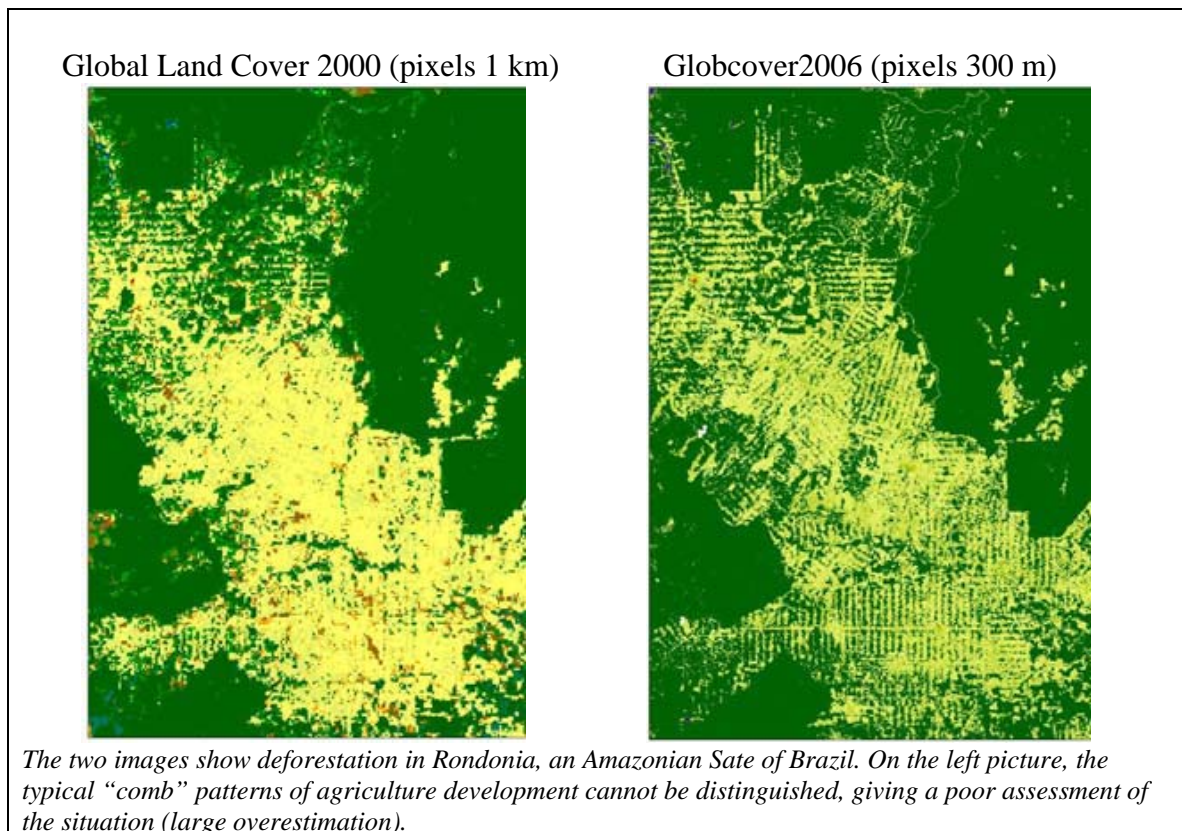
Two different cases need to be distinguished: high and low resolution images.

High resolution means pixels size between 10 and 30 meters. Often, the assumption is done that pixels are homogeneous and correlated to particular land cover types. This can be accepted for sufficiently large homogenous areas but leads to problems when the reality of the landscape is mosaics (like on the image from Kenya, above). The computer will classify pixels anyway on the basis of the training given, which is partly an artefact (because of low quality of automatic classifications in very mixed areas) and anyway a loss of information on landscape characters from an environmental perspective. Ironically, the argument has been turned against visual photo-interpretation, telling that in the case of agriculture the existence of mixed classes didn't allow producing good agriculture statistics. It is true if agriculture statistics are restricted to crops; it is not true if landscape patterns in agriculture matter, and it matters a lot from an environmental point of view.

When coming to low resolution satellite images (pixels of 1km²), the fiction of pure pixels cannot be maintained and mosaic classes come back of course in full such as “Mosaic Cropland / Tree Cover / Other natural vegetation” or “Mosaic Cropland / Shrub or Grass Cover” or “Mosaic Tree cover / Other natural vegetation” (as from Global Land Cover 2000 JRC/FAO/UNEP).

Towards a solution at the Global to Regional scales

Last year, the European Space Agency has delivered GlobCover 2006, the first global land cover map with 300m resolution. It is an automatic classification of monthly coverage of the planet by the Envisat/Meris satellite; it is based on LCCS. This is a major step forward as long as this medium resolution allows some change detection – much more problematic with 1 km² pixels. GlobCover is intended to be updated every year or second year.



In parallel to GlobCover, the EEA and ESA have launched a project called GlobCorine to support environmental assessments and land cover accounting. GlobCorine has three objectives. The first one is to support quick updates and nowcasting of Corine for responding the requirements of policy makers for fresh data matching the policy cycle. The second objective is to broaden the scope of land cover monitoring of Europe to its neighbourhood, namely Eastern Europe and the Southern Mediterranean. The third objective is supporting the implementation of ecosystem accounts at the global level.

Some limited revisions of the Globcover methodology are necessary in order to capture changes at the European and Global scales. In that respect, the LCCS legend was judged to be too complex for some aspects, resulting in problems in automatic classification.

A simplified legend has been established compatible with LCCS and Corine and matching minimum requirements in terms of change monitoring, studied before. Capturing land cover change for spatial monitoring is not independent from the detail of the classification. When aggregating the matrix of changes between two dates, there is a diagonal effect which annihilates changes falling inside a broader class. Ideally, maximum detail has to be obtained and then changes can be treated as flows of cover with a total remaining constant whatever aggregation is done. It is therefore important to have a high standardization of the land cover nomenclature in order to be able to compare change from one country to another.

When simplifying the nomenclature, it is important to keep the classes which are necessary to describe the observed changes. An example of the analysis carried out from the 44 Corine classes in order to assess limits to simplification is presented in annex 1.

In Europe the main land cover changes in relation to economic drivers and ecological impacts are: urban sprawl, agriculture internal conversion/arable land, agriculture internal conversion/fallow land and set asides, conversion of natural land to agriculture, withdrawal of farming, afforestation, deforestation, forest rotations. They make more than 80% of total land cover change in Europe. The number may look small but when cross with the various land cover types impacted, it gives a fairly good picture of the processes.

The working legend for GlobCorine retained is the following:

Level 1	Level 2
1. Artificial areas	1.1. Artificial areas
2. Arable land and permanent crops	2.1. Non-irrigated arable land
	2.2. Irrigated or post-flooded agriculture
	2.3. Permanent crops and associations
3. Pasture, grassland and mosaic farmland	3.1. Pastures and grassland
	3.2. Mosaic farmland
4. Forest and transitional woodland shrub	4.1. Standing forest
	4.2. Transitional woodland and shrub
5. Heathland and sclerophyllous vegetation	5.1. Heathland and sclerophyllous vegetation
6. Open space with little or no vegetation	6.1. Beaches, dunes, sand plains and bare rocks
	6.2. Sparsely vegetated areas
	6.3. Glaciers and perpetual snow
7. Wetlands	7.1. Forested wetlands
	7.2. Low vegetation and bare wetlands
8. Water bodies	8.1. Inland water bodies
	8.2. Coastal water bodies

It contains 8 classes at level 1 and 15 at level 2.

The classification process will benefit from the pre-classifications done for GlobCover and will lead to a re-labelling. Some compromises to GlobCover LCCS have been done: Urban as a single class; pasture and semi-natural/natural grassland are grouped; Forested wetlands are separated (as could be savannah or tundra the time being). Forests are not detailed, which means that it remains open for adopting LCCS breakdown. A particularity introduced is bringing closer forests and transitional woodland. This is important for change assessment as long as new felling and new plantation are the most important part of this category; without this grouping a gap with forest statistics would open up which consider as forest the forest territory as a whole.

Accounting for change

Land cover change cannot be mapped from the difference of two maps or of two pixels classifications. The combination of thematic and geometrical inaccuracies at each date makes the difference very uncertain. As stated before, the solution chosen by both Africover⁹ and Corine is to detect change directly by overlaying a map onto a satellite image. This is certainly the best solution at the regional/national scale and below but it requires some investment in money and time¹⁰. Under these conditions, updates make sense every 5 to 10 years.

It can be useful to monitor change more frequently. Even though, “on the average” total land cover change e.g. in Europe is circa 0.5% per year, it is in no way distributed evenly over the territory. Locally or regionally important processes can take place, with important risks of environmental damages. Light update procedures have to be implemented for that purpose. The same issue can be raised for the global scale, where “light” solutions have to be found as well. Two approaches can be foreseen and ideally combined: continuous detection of change with medium resolution images and sampling e.g. based on a regular grid.

Continuous detection of change combining map and satellite image in a semi-automated procedure is currently tested in the GlobCorine project¹¹. The methodology is based on the principle that a small number of basic changes can be assigned to objects. For the test, 3 objects and 5 changes are considered: urban sprawl (1), forest extension/reduction (2-3) and conversions within agriculture land between arable land and grassland (4-5). Because they are geo-referenced, the 5 flows on various types of land cover (e.g. wetlands, grassland, agriculture...) will produce additional information. Object by object, the change detection will not give a straight number but a probability which will have to be

⁹ See Multipurpose Africover Databases on Environmental Resources (MADE)

<http://www.africover.org/MADE.htm>

¹⁰ As an order of magnitude, the Corine land cover 2006 update for France (550 000 km²) has been achieved in 6 months by 4 photo-interpreters, plus 3 months of national supervision, plus management costs. This doesn't include the cost (moderate) of satellite images and of EEA quality control.

¹¹ *GlobCorine – A joint EEA-ESA project for operational land dynamics monitoring at pan-European scale*, S. Bontemps, P. Defourny, E. Van Bogaert, J.-L. Weber, O. Arino – forthcoming in proceedings 33rd International Symposium on Remote Sensing of Environment, Stresa, Italy, 4-8 May 2009

interpreted (threshold) according to external rules and data – therefore the results of regional statistics of change are included when they are available.

Another data source for forests is the FRA2010 survey launched by FAO altogether with the EC Joint Research Centre, NASA and USGS.

“The primary aims of the new global survey are to obtain information on the distribution of forests and on changes in forest area over time at regional, biome and global levels. It will complement, build on and in some cases strengthen national inventory systems but will not replace them.

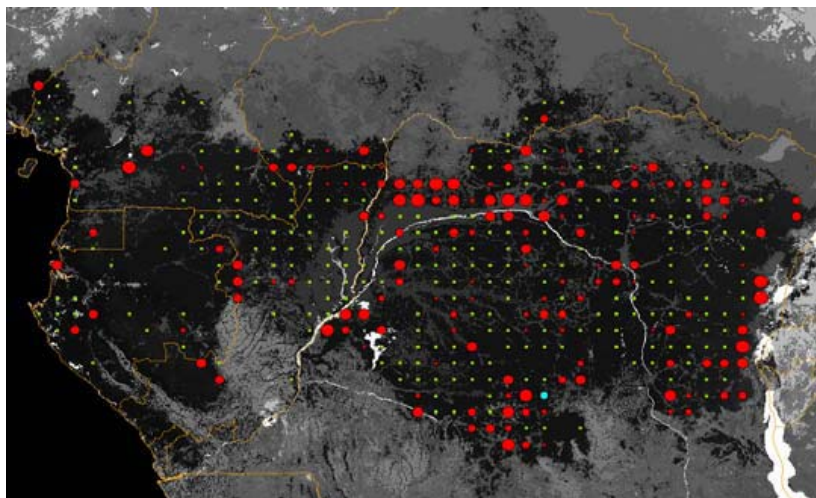
The survey has two main components:

- *Generating a new, validated global tree cover map using time-series imagery from MODIS satellites at 250 m resolution.*
- *Gathering and analysing the best existing global imagery (Landsat images at 30 m resolution) from 1975, 1990, 2000 and 2005 for improved estimates of forest area and forest area change.*

...

Selection of archival Landsat satellite images (at 30 m resolution) at more than 10 000 locations across the planet will provide a comprehensive sample of the world’s land surface in 1975, 1990, 2000 and 2005. Each sample tile will cover a 10 by 10 km square at every junction of one degree of latitude and longitude (approximately 100 km apart). Images will be processed to provide statistically reliable estimates of forest extent and change at regional, biome and global levels. This will reveal which forest types are changing the most.”¹²

FRA2010 results will be available in 2010.



Example of change (red dots) in forest monitored by FRA2010.

¹² Source: FAO/JRC brochure *Seeing the forest... not just the trees*. www.fao.org/forestry/fra2010-remotesensing

Field area sampling surveys gives traditionally good statistical results at the parcel level. They are statistically more accurate than remote sensing surveys but their geographical resolution is very low, which limits their use. When land cover accounts based on satellite images can be computed by any types of spatial breakdowns (catchments and sub-catchments, coastal zones, mountain areas, administrative regions etc...) statistics from field sampling surveys are relevant for countries or large regions (in the best case of a fairly high number of points) only. However, cross fertilisation can be sought between the two approaches. Field surveys can be stratified by land cover types. Satellite image classification can highly benefit from field surveys for QA/QC¹³ at points level as well as statistically.

If available regularly updated cadastre data can as well be used for updating land accounts, alone or in conjunction with satellite images.

Land cover flows classification

Land cover flows are groupings of changes according to the processes taking place. A land cover flows classification has been established by the EEA for land cover accounting¹⁴. It comprises 3 hierarchical levels of respectively 9, 38 and 55 classes. The detail with explanatory notes is attached in Annex 2. A similar nomenclature has successfully being implemented in the Burkina Faso BDOT project.

An international nomenclature should stick to a small number of classes matching the main dynamics as already mentioned above. The details should also take into account the practical possibilities given by the observation system used.

In the case of GlobCorine, the nomenclature expected to be met is the following

- A. Urban sprawl
- B. Internal conversions within in agriculture land/ intensification
- C. Internal conversions within in agriculture land/ extension of grassland
- D. Conversion of forested and natural land to agriculture
- E. Withdrawal of farming with and without forest creation
- F. Conversions within forested land/ recent felling and new transitions
- G. Conversion of transitional land to forest
- H. Forest creation, afforestation of natural land
- I. Water bodies creation and management (tentative)
- J. Change due to natural and multiple causes (tentative)

A more or less detailed level 2 can be derived from the identification of the land cover classes consumed by the various processes. Therefore, deforestation will be described as

¹³ This is what is done in Europe where Corine land cover is controlled using LUCAS (the Agri-environmental area sampling survey of Eurostat).

¹⁴ Land Accounts for Europe 1990-2000, EEA Report 11, 2006
http://www.eea.europa.eu/publications/eea_report_2006_11

A./Forest plus B./Forest (note that F. remains a transitional situation either turning back to forest (replantation) or forward to deforestation of A. or B. type).

The practical validation of this nomenclature can be envisaged in the GlobCorine project by the end of 2009. The input of FRA2010 for forest change will have to be assessed at that time. Most likely further adjustments will be necessary, for making the best use of the two sources of information.

From Global to National scales: detailing nomenclatures [to be developed]

Land cover stocks: As recognized earlier in this paper, there is not only one solution for land cover mapping which has in any case to fit for purpose. If it is important to have a standard land cover simplified nomenclature, national breakdown may differ because of the reference to one or the other international classification system – LCCS or Corine – as well as because of the existence of national variants in several countries. According to purposes one may prefer using LCCS (which emphasises the analysis of vegetation patterns and provides much detail on agriculture and forests) or Corine (which emphasises landscape patterns and pays more attention to artificial land classes), or any other solution.

Land cover flows: the detail of the classification is determined by that of stocks, which means ultimately by purpose and data availability. One can consider that national breakdowns are limited to a too small number of cases (e.g. for recording conversions and land recycling within urban areas between residential, economic activities and green urban areas).

Proposals for discussion

1. Use GlobCorine to test the feasibility of a standard simplified international land cover nomenclature/legend at the medium scale (circa 1/ 500 000)
2. Organise early in 2010 a workshop with main stakeholders to come to a consensus on such summary land cover nomenclature/legend.
3. Revise the draft summary classification of land cover flows according to conclusions of the workshop on land cover nomenclature. Submit this revision to the first London Group meeting in 2010.
4. Keep guidance for the national level application of land cover accounts open and flexible. Encourage legends translations in order to facilitate multiple reporting.
5. Start drafting a provisional outline of a chapter on land cover accounts for submission to the next LG meeting.

Annex 1: Example of analysis of possible information loss on land cover change due to the use of a too aggregated map.

The analysis has been carried out for 4 countries in Europe and lead to similar results. Corine classes are labelled with 1, 2 or 3 digits. They have been grouped stepwise with the purpose of minimizing the diagonal effect, where internal changes are not identified anymore. In the case of the “1” classes (Artificial land), the aggregation leads to a loss of information of circa 10% of total change. This is inherent to cartographic analysis which is scale dependant. It means that explicit adjustments for scale effects have to be introduced when comparing two accounts produced at different scales.

Country : SK Slovakia
 Period 1990 - 2000
 Nb years: 10 --> FINAL Data
 Region (s) : All
 Elevation breakdown (s) : All
 Dominant Land Cover Type (s) : All
 River basin (s) : All
 Distance to shoreline (s) : All
 Effects of aggregation (diagonal with aggregated)

LC2000		111112	12&13	141142	1	211212	213	21	221222	223
LC1990										
111112		0	25	0	25	2		2	0	
12&13		221	282	0	503	38		38	0	
141142		7	23	0	30	0		0		
1		228	331	0	558	41		41	0	
211212		1841	1111	7	2959				1112	
213										
21		1841	1111	7	2959				1112	
221222		139	11		150	5187		5187	44	
223										
22		139	11		150	5187		5187	44	
241										
2A		1980	1122	7	3109	5187		5187	1156	
231		73	188	49	310	7803		7803	1	
242_3_4		756	350	81	1187	4590		4590	41	
2B		829	538	130	1496	12393		12393	42	
31		53	446	132	630	26		26	0	
324		21	12	40	73	34		34		
3A		74	457	172	704	59		59	0	
321322						0		0	0	
323										
3B						0		0	0	
3C										
4		0		3	3	0		0		
5		7	11	0	18	1		1		

Relative loss of observed change due to aggregation (%)	0	11	0	9				4	
Diagonal effect of aggregation	0	282	0	558				44	
Non consolidated change 2000 (+) clc44	3118	2459	313	5889	17680		17680	1198	
Non consolidated clc44 diagonal (no change)	222228	36192	10716	269136	1634844		1634844	34691	
Grand Total	225346	38651	11028	275025	1652524		1652524	35890	

Annex 2: Classification of land cover flows for EEA's Land accounts (LEAC)

A: Definition of land cover flows

LCF1 Urban land management: Internal transformation of urban areas

LCF11 Urban development/infilling: Conversion from discontinuous urban fabric, green urban areas and sport and leisure facilities to dense urban fabric, economic areas and infrastructures

LCF12 Recycling of developed urban land: Internal conversions between residential and/or non-residential land cover types. Construction of urban greenfields is not considered here but as

LCF11

LCF13 Development of green urban areas: Extension of green urban areas over developed land as well as, in the periphery of cities, over other types of land uses

LCF2 Urban residential sprawl: Land uptake by residential buildings altogether with associated services and urban infrastructure (classified in CLC111 and 112) from non-urban land (extension over sea may happen)

LCF21 Urban dense residential sprawl: Land uptake by continuous urban fabric (CLC111) from non-urban land

LCF22 Urban diffuse residential sprawl: Land uptake by discontinuous urban fabric (CLC112) from non-urban land

LCF3 Sprawl of economic sites and infrastructures: Land uptake by new economic sites and infrastructures (including sport and leisure facilities) from non-urban land (extension over sea may happen)

LCF31 Sprawl of industrial and commercial sites: Non-urban land uptake by new industrial and commercial sites

LCF32 Sprawl of transport networks: Non-urban land uptake by new transport networks (note that linear features narrower than 100 m are not monitored by CLC)

LCF33 Sprawl of harbours: Development of harbours over non-urban land and sea

LCF34 Sprawl of airports: Development of airports over non-urban land and sea

LCF35 Sprawl of mines and quarrying areas: Non-urban land uptake by mines and quarries

LCF36 Sprawl of dump sites: Non-urban land uptake by waste dump sites

LCF37 Construction: Extension over non-urban land of areas under construction during the period (note: covers mainly construction of economic sites and infrastructures)

LCF38 Sprawl of sport and leisure facilities: Conversion from developed as well as non-urban land to sport and leisure facilities

LCF4 Agriculture internal conversions: Conversion between farming types. Rotation between annual crops is not monitored by CLC

LCF41 Extension of set aside fallow land and pasture: Conversion from crop land to grassland as an agricultural rotation or for cattle husbandry

LCF411 Uniform extension of set aside fallow land and pasture: Large parcels conversion from crop land to grassland

LCF412 Diffuse extension of set aside fallow land and pasture: Conversion from crop land to complex cultivation patterns (with grassland) and from mixed agriculture to large pasture parcels

LCF42 Internal conversions between annual crops: Conversions between irrigated and non-irrigated agriculture

LCF421 Conversion from arable land to permanent irrigation perimeters: Extension of permanent irrigation (incl. rice fields) over arable land

LCF422 Other internal conversions of arable land: Other conversions between arable land and irrigated perimeters, incl. rice fields

LCF43 Internal conversions between permanent crops: Conversions between vineyards, orchards and/or olive groves

LCF431 Conversion from olives groves to vineyards and orchards: Conversion from olives groves to vineyards and orchards

LCF432 Conversion from vineyards and orchards to olive groves: Conversion from vineyards and orchards to olive groves

LCF433 Other conversions between vineyards and orchards: Other conversions between vineyards and orchards

LCF44 Conversion from permanent crops to arable land: Conversion from vineyards, orchards and olive groves to irrigated and/or non-irrigated arable land

LCF441 Conversion from permanent crops to permanent irrigation perimeters: Conversion from permanent crops (incl. when associated with arable land — CLC241) to permanent (large) irrigation perimeters and rice fields

LCF442 Conversion from vineyards and orchards to non-irrigated arable land: Conversion from vineyards and orchards to non-irrigated arable land and from associations of annual and permanent crops to uniform arable land

LCF443 Conversion from olive groves to non-irrigated arable land: Conversion from olive groves to non-irrigated arable land, incl. conversions to associations of annual and permanent crops (CLC241) and of crops and pasture (CLC242)

LCF444 Diffuse conversion from permanent crops to arable land: Conversion from vineyards and orchards to associations of annual and permanent crops (CLC241) and of crops and pasture (CLC242: complex cultivation patterns)

LCF45 Conversion from arable land to permanent crops: Plantation of vineyards, orchards and olive groves on arable land

LCF451 Conversion from arable land to vineyards and orchards: Plantation of vineyards, orchards on arable land

LCF452 Conversion from arable land to olive groves: Plantation of olive groves on arable land

LCF453 Diffuse conversion from arable land to permanent crops: Conversion from uniform arable land to associations of permanent crops and annual crops (CLC241)

LCF46 Conversion from pasture to arable and permanent crops: Conversion from pasture to arable and permanent crops

LCF461 Conversion from pasture to permanent irrigation perimeters: Conversion of uniform pasture areas to permanent irrigation perimeters

LCF462 Intensive conversion from pasture to non-irrigated arable land and permanent crops: Conversion of uniform pasture areas to non-irrigated annual and permanent crops

LCF463 Diffuse conversion from pasture to arable and permanent crops: Conversion from complex cultivation patterns including pasture (CLC242) to uniform arable land and permanent crops as well as to associations of the last two (CLC241) and conversion of uniform pasture (CLC231) to complex cultivation patterns

LCF47 Extension of agro-forestry: Conversion of cultivated land and open pasture to agro-forestry systems such as dehesas and montanas (note: conversion from 243 to 244, where natural vegetation is important, is recorded under LCF522)

LCF48 Other conversions from agriculture mosaics to arable land and permanent crops: This land cover class is used only when changes are detected from a Corine land cover matrix combining classification of level 2 for the initial year and level 3 for the final year. Agriculture mosaic classes being grouped in CLC24 only, it is not possible to differentiate the processes according to the type of land consumed. It includes in particular the sub-class LCF523, conversions from agriculture-nature mosaics to continuous agriculture, not isolated in this case

LCF481 Other conversions from agriculture mosaics to permanent crops: Used for CLC level 2 x level 3 only. It includes conversion of agriculture-nature mosaics to arable land (see LCF48)

LCF482 Other conversions from agriculture mosaics to arable land (including conversion of agriculture-nature mosaics to permanent crops). Used for CLC level 2 x level 3 only. It includes conversion of agriculture-nature mosaics to arable land (see LCF48)

LCF5 Conversion from forested and natural land to agriculture: Extension of agriculture land use

LCF51 Conversion from forest to agriculture: Deforestation for agriculture purpose, including agricultural conversion of transitional woodland shrub

LCF511 Intensive conversion from forest to agriculture: Deforestation, including agricultural conversion of transitional woodland shrub, for cultivation of annual and permanent crops (incl. in association, CLC241)

LCF512 Diffuse conversion from forest to agriculture: Conversion from uniform forest to complex cultivation patterns, mosaic agricultural landscape and agro-forestry. Due to possible uncertainties in monitoring extension of pasture vs. recent felling, conversion from forests to pasture land (CLC231) is recorded here

LCF52 Conversion from semi-natural land to agriculture: Conversion from dry semi-natural land (except CLC324, grouped with forests) to agriculture

LCF521 Intensive conversion from semi-natural land to agriculture: Conversion from dry semi-natural land (except CLC324, grouped with forests) to annual crops, permanent crops and their association

LCF522 Diffuse conversion from semi-natural land to agriculture: Conversion from dry semi-natural land (except CLC324, grouped with forests) to pasture and mixed agriculture with pasture

LCF523 Conversions from agriculture-nature mosaics to continuous agriculture: Conversion from CLC243, where natural areas are distinctive feature of the land systems to continuous agriculture. This is an over-estimation from an agriculture perspective but is justified in terms of analysis of ecological potentials of complex land systems

LCF53 Conversion from wetlands to agriculture: Conversion of wetlands to any type of farmland (CLC2)

LCF54 Conversion from developed areas to agriculture: Conversion of urban land to any type of farmland (CLC2)

LCF6 Withdrawal of farming: Farmland abandonment and other conversions from agriculture activity in favour of forests or natural land

LCF61 Withdrawal of farming with woodland creation: Forest and woodland creation (incl. transitional woodland shrub) from all CLC agriculture types. Withdrawal of farming with woodland creation is a broader concept than farmland abandonment with woodland creation, which results more from decline of agriculture than afforestation programmes. Additional information is necessary to identify an abandonment process (type of agriculture, landscape type, socio-economic statistics...)

LCF62 Withdrawal of farming without significant woodland creation: Farmland abandonment in favour of natural or semi-natural landscape (except forests and transitional woodland shrub), as long as they are a possible transition. Some odd cases are provisionally recorded as LCF99 Other changes and unknown

LCF7 Forests creation and management: Creation of forests and management of the forest territory by felling and replanting. Due to the CLC cycle of 10 years, only one part of the shrubs are tall enough to be identified as trees. In order to taking stock of all recent plantations, conversions of semi-natural land to CLC324 are conventionally recorded as afforestation (although some natural colonisation may take place). In the case of conversion from farmland, see LCF61

LCF71 Conversion from transitional woodland to forest: Conversion from transitional woodland to broadleaved, coniferous or mixed forest, taking place when shrubs can be detected as trees

LCF72 Forest creation, afforestation: Forest creation and afforestation take place on all previously non-agricultural landscapes where new forests can be identified. Extension of transitional woodland shrub over non-agricultural land is recorded as afforestation. Conversions from transitional woodland to broadleaved, coniferous or mixed forest are not a creation of forest territory and are therefore registered separately (LCF71)

LCF73 Forests internal conversions: Conversions between broadleaved, coniferous and/or mixed forest (CLC311, 312 and 313)

LCF74 Recent felling and transition: Conversion from broadleaved, coniferous and/or mixed forest to open semi-natural and natural dry land resulting more likely from felling. The main transition is towards CLC324 Transitional woodland shrub, although some other types can be detected. Due to uncertainties, all are provisionally considered as transitional states of forests

LCF8 Water bodies creation and management: Creation of dams and reservoirs and possible consequences of the management of the water resource on the water surface area

LCF81 Water bodies creation: Extension of water surfaces resulting from the creation of dams and reservoirs

LCF82 Water bodies management: Consequences of the management of the water resource on the water surface area of reservoirs

LCF9 Changes of land cover due to natural and multiple causes: Changes in land cover resulting from natural phenomena with or without any human influence

LCF91 Semi-natural creation and rotation: Changes in natural and semi-natural land cover due to natural factors

LCF911 Semi-natural creation: Natural colonisation of land previously used by human activities. Note that extension of CLC324 is considered as the result of farmland abandonment or direct afforestation

LCF912 Semi-natural rotation: Rotation between the dry semi-natural and natural land cover types of CLC (except forest and transitional woodland shrub)

LCF913 Extension of water courses: Results from natural erosion and artificial works.

Due to the very incomplete detection of rivers with CLC, the LCF913 flow item has to be used very carefully

LCF92 Forests and shrubs fires: Due to the short cycle of recovery of vegetation from fire, burnt areas (which are well identified on satellite images) cannot be compared in a ten-year interval, except for very aggregated statistics

LCF93 Coastal erosion: Conversion of all land cover types to intertidal flats, estuaries or sea and ocean. The tide level when the satellite image is shot being unknown of the photointerpretors, the coastal erosion flow has to be used very carefully

LCF94 Decrease in permanent snow and glaciers cover: Decrease of permanent snow and glaciers due to climate change to semi-natural and natural land covers, mainly to bare rock, sparsely vegetated areas and water systems

LCF99 Other changes and unknown: In this category are recorded land cover changes that are rare or more likely improbable