Development of methodology to eliminate contradictions between CLC-Change$_{1990-2000}$ and CLC-Change$_{2000-2006}$

Final draft

Prepared by:
G. Maucha, Gy. Büttner and R. Pataki

Date:
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Project Manager:
G. Büttner

European Environment Agency

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1 INTRODUCTION: WHAT IS THE PROBLEM?

Two European CORINE Land Cover Change (CLC-Change) datasets were produced during the CLC2000 and CLC2006 campaigns:

- CLC-Change(1990-2000);
- CLC-Change(2000-2006)

As the second CLC change mapping (in CLC2006) was not harmonized with the results of the first CLC change mapping (in CLC2000), geometric and thematic contradictions might occur between the two CLC change maps. The aim of this report is to define the extent of this problem and to suggest a methodology to eliminate – or reduce, as far as possible – these contradictions in order to provide more consolidated data for the users.

The work belongs to task 261.1_1 in the ETC-SIA 2011 Implementation Plan under the title: CLC2006 and update of time series.

1.1 CLC-CHANGE(1990-2000) DATABASE

This CLC-Change dataset differs from the next ones in quality, because:

In the CLC2000 campaign the methodology of change mapping was not uniform. Most of the countries derived CLC changes as the difference (intersection) of the two status layers (CLC1990 and CLC2000 databases). This provided an underestimation of the amount of the mapped change polygons, not all real CLC changes (larger than 5 ha) were mapped [1]. On the other hand difference between CLC2000 and CLC1990 often included non-real changes, yielding an overestimation of change area.

As the first CLC inventory (CLC1990) represents a broad range of reference dates (from 1985 to 1998), change polygons in the CLC-Change(1990-2000) database represent different time periods country by country, varying from 1985-1998 (Portugal) to 1995-2000 (Slovenia).

1.2 CLC-CHANGE(2000-2006) DATABASE

During the CLC2006 campaign the problems listed above were mostly eliminated. A uniform mapping methodology was introduced for mapping CLC changes: all changes larger than 5 ha were mapped. In CLC2006 project the "change mapping first" mapping methodology was preferred by EEA [2]. These modifications in methodology resulted a homogenous CLC-Change database for Europe. The planned CLC2012 campaign will be carried out under similar methodological conditions.

During the CLC2006 change mapping, the pervious change layer - CLC-Change(1990-2000) database - was not taken into account, therefore geometrical and thematic contradictions may occur between the two CLC change layers on areas where both datasets include changes.

1.3 CLC-CHANGE(2000-2006) DATABASE

In total 29 European countries are covered with two CLC-Change databases (Table 1). Two of them, Malta and Liechtenstein has practically no changes to harmonise. Turkey is just working on their CLC-Change(1990-2000) database, results are expected by autumn 2011. European integration of CLC2006_UK dataset is under way, and data will be available in July 2011. Altogether 26 countries will be included in this harmonisation exercise.

Table 1 Availability of CLC databases produced during the three inventories

country		country area, km²	CLC1990	CLC2000	CLC2006
AL	Albania	28748		+1	+
AT	Austria	83850	+	+	+
BE	Belgium	30520	+	+	+
BA	Bosnia-Herzegovina	51129		+1	+
BG	Bulgaria	110993	+	+	+
CR	Croatia	56542	+2	+	+
CY	Cyprus	9251		+	+
CZ	Czech Republic	78864	+	+	+
DK	Denmark	43090	+	+	+
EE	Estonia	45226	+	+	+
FI	Finland	338130		+	+
FR	France	551500	+	+	+
DE	Germany	356910	+	+	+
GR	Greece	131990	+	+	
HU	Hungary	93030	+	+	+
IS	Iceland	103000		+3	+
IE	Ireland	70283	+	+	+
IT	Italy	301270	+	+	+
KV	Kosovo	10908		+	+
LV	Latvia	63700	+	+	+
LI	Liechtenstein	160	+	+	+
LT	Lithuania	65200	+	+	+
LU	Luxemburg	2590	+	+	+
MK	Macedonia (FYROM)	25713		+1	+
MT	Malta	316	+	+	+
ME	Montenegro	13812	+2	+	+
NL	Netherlands	35398	+	+	+
NO	Norway	323877		+	+
PL	Poland	312685	+	+	+
PT	Portugal	88971	+	+	+
RO	Romania	237500	+	+	+
RS	Serbia	88361	+2	+	+
SK	Slovak Republic	49035	+	+	+
SI	Slovenia	20273	+	+	+
ES	Spain	504780	+	+	+
SE	Sweden	449960		+	+
CH	Switzerland	41293		+	+
TR	Turkey (CLC2006)	789452	+4	+	+
UK	United Kingdom	244880	+6	+	+5
	Total:	**5853190**	**29**	**39**	**38**

Remarks:

+: standard CLC

+1: CLC produced in late 1990's was considered as CLC2000 (AL, BA, MK)

+2: CLC1990 and CLC-Change(1990-2000) produced by backdating as part of CLC2000 project (CR, ME, RS)

+3: CLC2000 and CLC-Change(2000-2006) produced by backdating as part of CLC2006 project (IS)

+4: Turkey is producing a CLC1990 and CLC-Change(1990-2000) database by backdating CLC2000

+5: Integration of CLC2006_UK dataset is under way (June 2011)

+6: CLC1990 is not available. CLC-Change(1990-2000) was produced by backdating of CLC2000.

1.4 NEED FOR A MULTI-DATE CLC-CHANGE DATABASE

Traditionally, CLC-Change databases indicated land cover changes between two explicit reference dates. However, there is an evolving need for time-continuous land monitoring results. The existence of two CLC-change databases (3 reference dates) already indicates the problems to solve.

Practical experiences showed, that while delineation of change features between two reference dates is operatively applicable (see CLC mapping approach), the follow-up of the evolution of change features by more than two reference dates becomes more and more a complex issue.

A practical solution to this problem is to keep the vector geometry in the original CLC-Change databases representing two dates, but fix the geometry in case of multi-date change databases. The plausible solution is to use the widely used 100m LAEA grid for managing multi-date CLC-Change data. If the geometry is fixed, only CLC codes have to be determined (or harmonized) for each 100x100m cell.

2 THE EXTENT OF THE PROBLEM

Currently CLC-Change(1990-2000) and CLC-Change(2000-2006) datasets are available for 24 European countries (June 2011). In 2nd half of 2011, this coverage will be supplemented with two more countries (TR and UK).

Based on the comparison of European 100 m raster datasets, altogether 93 077 ha area (931 km^2) was found to contain contradiction of codes (practically CLC2000 codes) in CLC-Change databases, which corresponds to approximately 1% of all changed area (see Table 2). This area is made up by 9 471 polygons.

Table 2 Size of contradictory areas between the two CLC-Change datasets, by country

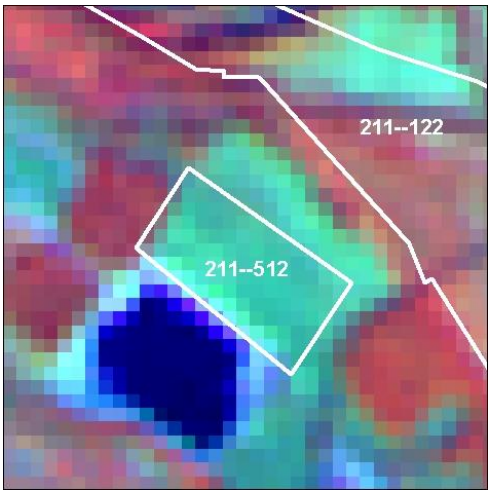
Country	CLC-Change (1990-2000) area (ha)	CLC-Change (2000-2006) area (ha)	Contradictions (ha)	Percent of CLC-Change (1990-2000)
AT	36 305	38 853	264	0,73%
BE	53 629	18 619	353	0,66%
BG	122 325	57 972	699	0,57%
CR	106 794	55 798	932	0,87%
CZ	510 262	157 828	13 045	2,56%
DE	853 879	221 090	4 454	0,52%
DK	56 357	33 126	247	0,44%
EE	120 177	103 428	80	0,07%
ES	2 380 489	865 386	27 560	1,16%
FR	1 115 475	370 195	7 561	0,68%
HU	415 788	266 075	5 943	1,43%
IE	560 745	161 316	6 903	1,23%
IT	393 885	181 052	2 257	0,57%
LT	156 480	99 684	154	0,10%
LU	4 209	3 555	84	2,00%
LV	251 838	147 630	24	0,01%
ME	2 791	3 585	5	0,18%
NL	168 503	64 673	2 620	1,55%
PL	254 602	182 397	2 811	1,10%
PT	975 807	765 146	13 784	1,41%
RO	309 994	76 605	1 104	0,36%
RS	84 101	45 071	676	0,80%
SI	2 353	3 029	2	0,08%
SK	200 295	74 433	1 455	0,73%
Sum	**9 136 417**	**4 028 402**	**93 077**	**1.02%**

These figures show that the problem of contradiction between the two CLC-Change datasets is rather marginal. On a European average a mere 1% of all CLC change areas is contradictory, meaning that their CLC2000 codes are not identical if we compare CLC-Change(1990-2000) and CLC-Change(2000-2006). The highest percent of contradiction was found in Czech Republic (2.56%), while the lowest in Latvia (0.01%).

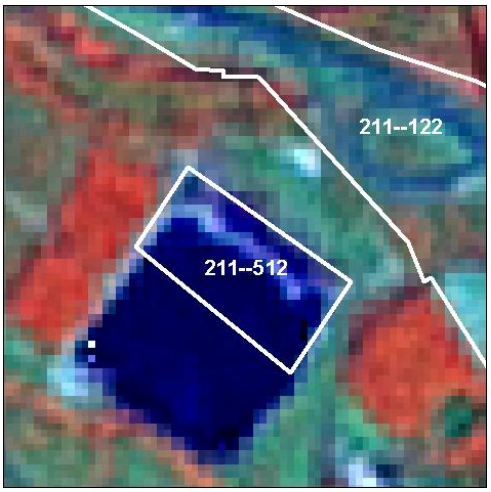
3 CASES OF CONTRADICTION (EXAMPLES)

Contradictions are detected as non-agreement between CLC codes of the same area regarding year 2000 (as central/common year) of two CLC-Change datasets (Fig. 1-3).

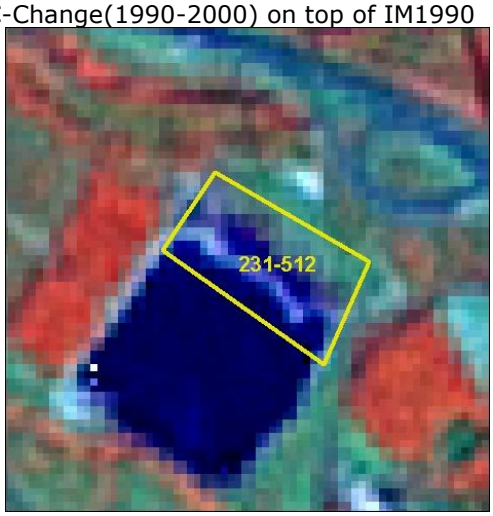
Figure 1 Enlargement of a lake (gravel extraction site) as mapped in two consecutive CLC-Change databases (see more explanations on page 10)



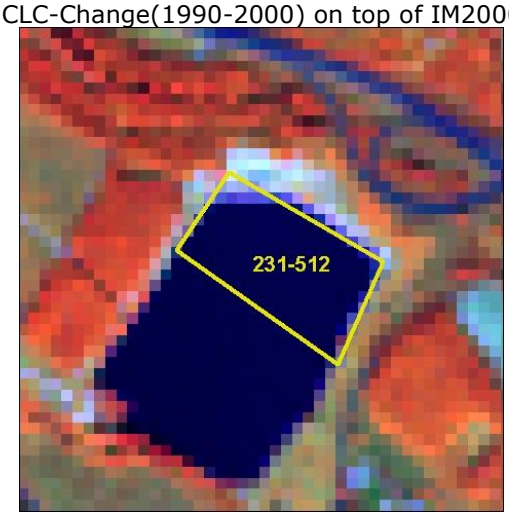
CLC-Change(1990-2000) on top of IM1990



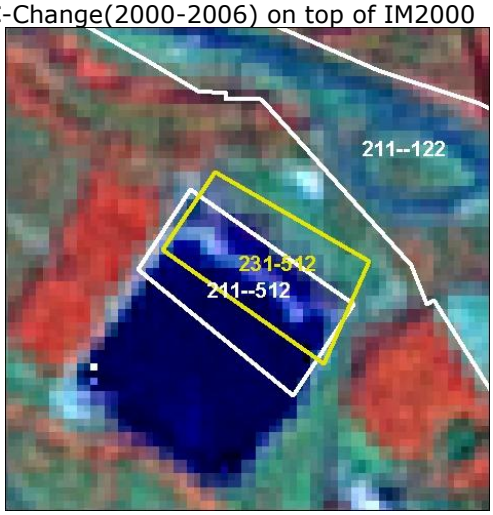
CLC-Change(1990-2000) on top of IM2000



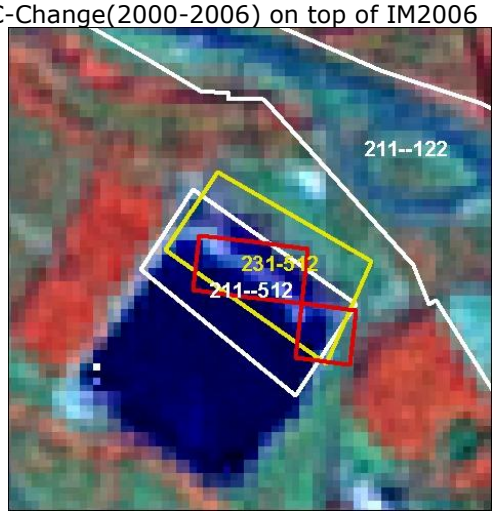
CLC-Change(2000-2006) on top of IM2000



CLC-Change(2000-2006) on top of IM2006

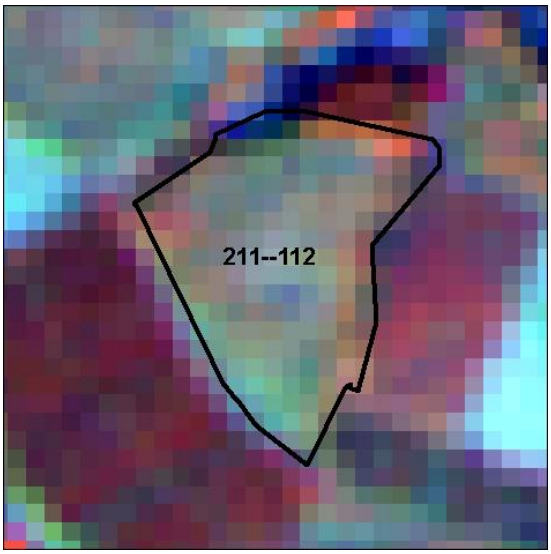


Overlap of CLC-Change data. Polygon size: 6 ha

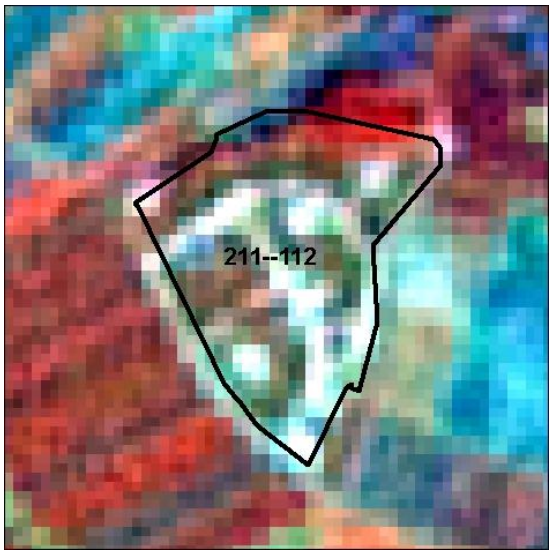


Difference in rasterized CLC-Change data (red)

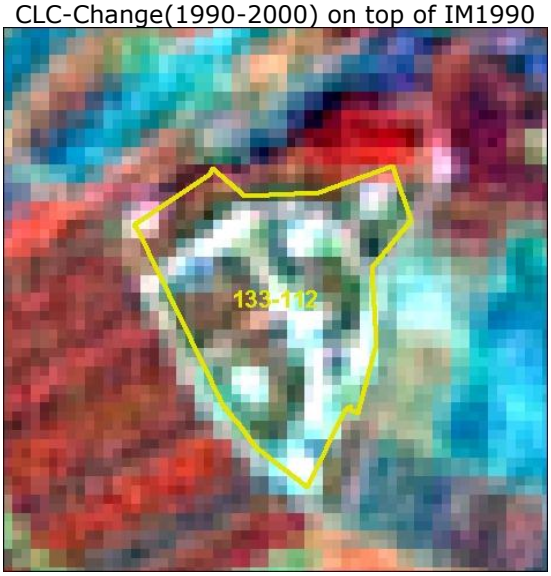
Figure 2 Development of a new built-up area as mapped in two consecutive CLC-Change projects (see more explanations on page 10)



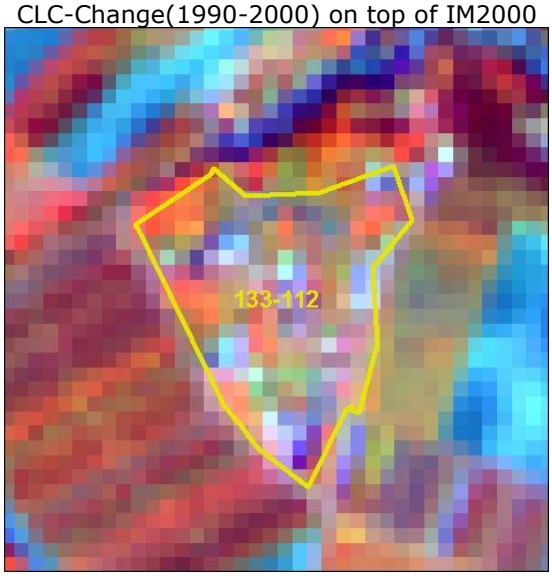
CLC-Change(1990-2000) on top of IM1990



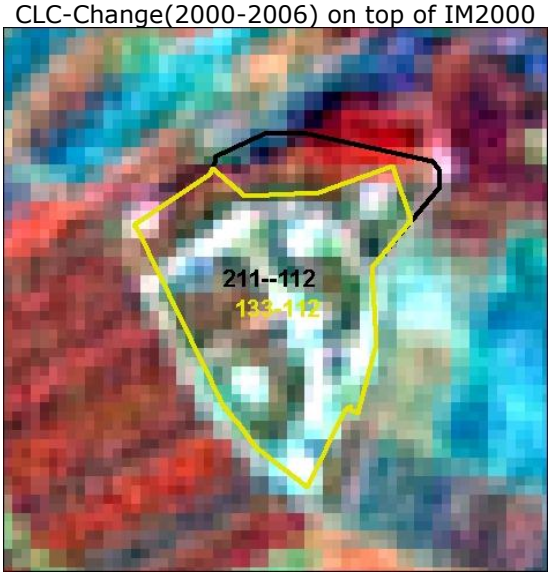
CLC-Change(1990-2000) on top of IM2000



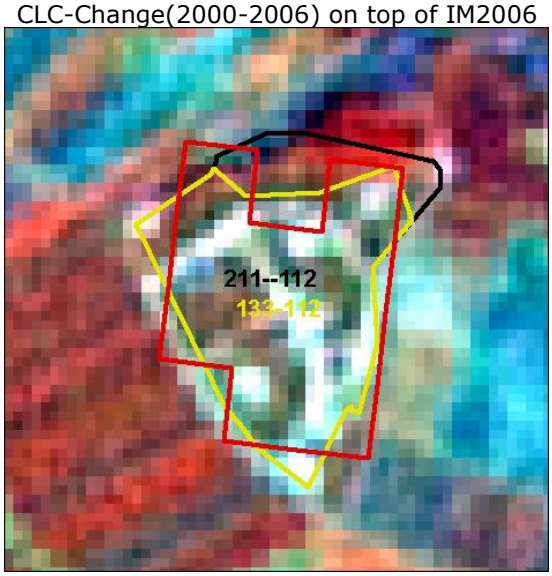
CLC-Change(2000-2006) on top of IM2000



CLC-Change(2000-2006) on top of IM2006

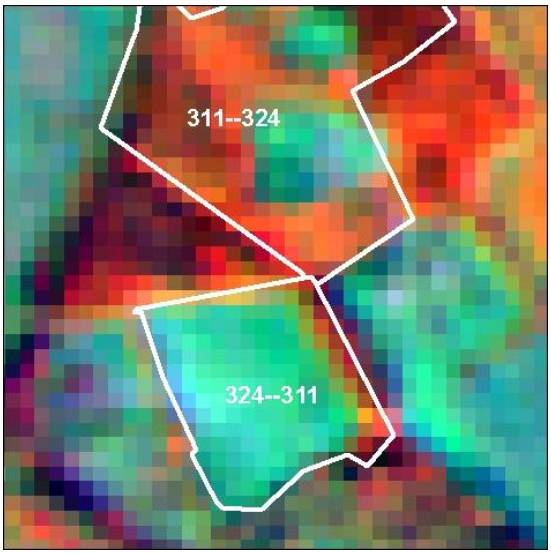


Overlapping CLC-Change data on IM2000.
Polygon sizes: 9 and 11 ha

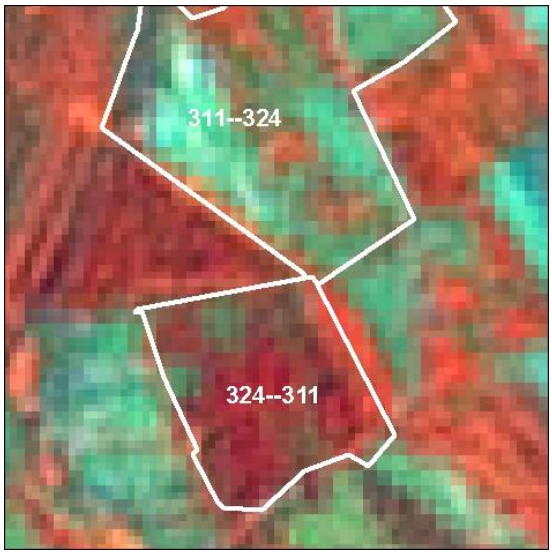


Difference in rasterized CLC-Change data (red)

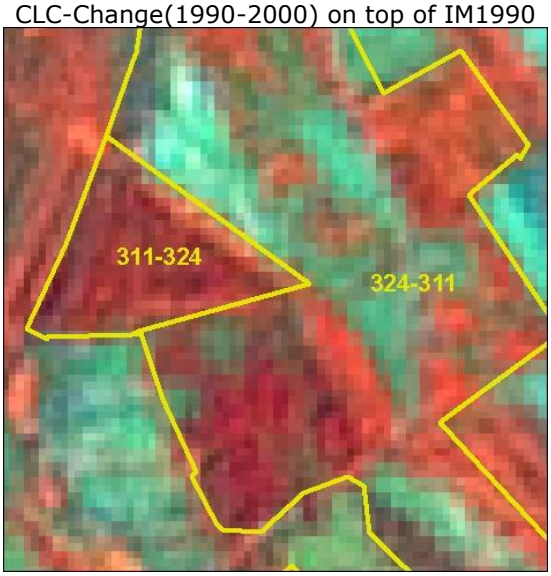
Figure 3 Neighbouring forestry changes as mapped in two consecutive CLC-Change projects (see more explanations on page 10)



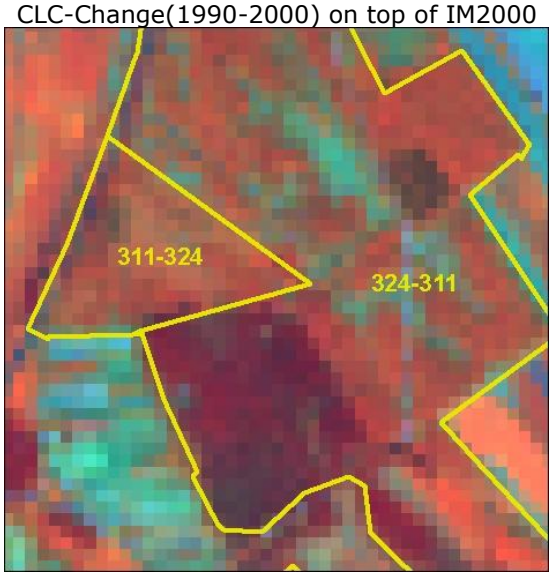
CLC-Change(1990-2000) on top of IM1990



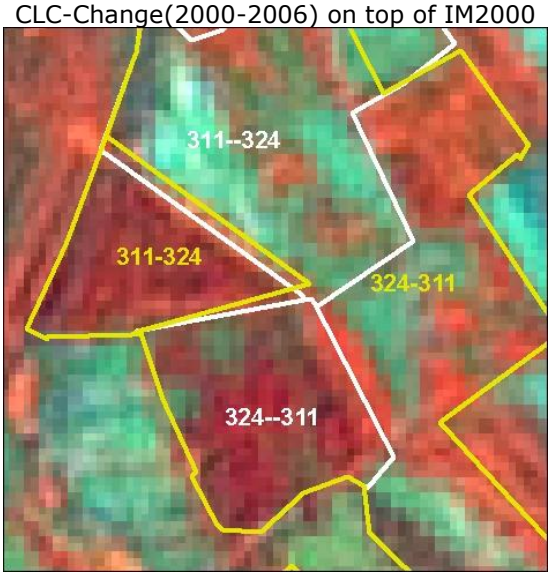
CLC-Change(1990-2000) on top of IM2000



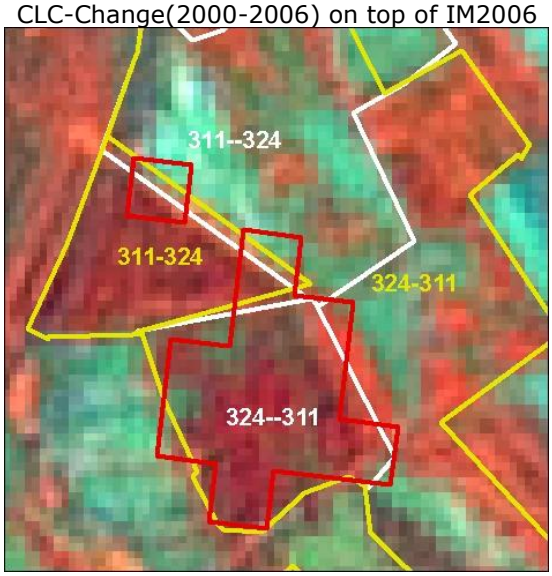
CLC-Change(2000-2006) on top of IM2000



CLC-Change(2000-2006) on top of IM2006



Overlapping CLC-Change data on IM2000. Polygon size: 11 ha



Difference in rasterized CLC-Change data (red). The single cell polygon should be considered noise.

On Figure 1 (top) we see a 6 ha change from arable land (in 1990) to water body (in 2000). It was correctly coded as 211-512. As the increased water body's size was still below 25 ha, this feature was not represented in CLC2000. Between 2000 and 2006 (Figure 1, middle) the lake has further increased. This case pasture to water body change (231-512) was mapped (6 ha). This change was a bit exaggerated in area in order to reach the 5 ha mapping limit. The two change polygons have 3 ha overlap, where codes of two changes over the same area i.e. 211-512 and 231-512 are contradicting each other. The task of harmonisation is to provide a common CLC2000 code as a "compromise". The solution is coding it as 512, which means "no-change" for the overlap area between 2000 and 2006. Note that the remaining 231-512 area in CLC-Change(2000-2006) will be smaller than 5 ha.

On Figure 2 (top) we see a 11 ha change from arable land (in 1990) to built-up (in 2000). 211-112 was mapped, which was not correct, as the area in 2000 was still rather a construction site (133). Therefore the correct coding would have been 211-133. Between 2000 and 2006 (Figure 2, middle) the area became really residential. Here the right process was mapped (133-112). Area coverage was a bit smaller than before (9 ha). Consequently, the (almost) fully overlapping two change polygons are in contradiction, because of two incompatible changes over the same area i.e. 211-112 and 133-112. The task of harmonisation is to provide a common CLC2000 code as a "compromise". Here the solution is evident; the right common CLC2000 code is 133.

On Fig. 3 (top) a 11 ha area was correctly mapped as forest growth (324-311) between 1990 and 2000. In 2006 (Fig. 3, middle) a large area (219 ha) was mapped as forest growth (324-311). This change area includes the previously mapped change area as well. If we compare IMAGE2000 and IMAGE2006 we see some forest development between 2000 and 2006. We have a 11 ha area with contradictory change, because of two, incompatible changes over the same area: 324-311 and 324-311. The task of harmonisation is to provide a common CLC2000 code as "compromise". Here the right CLC2000 code is 311. Consequently the area in question will have no change in CLC2006.

As result of delineation inconsistency between CLC2000 and CLC2006, a single cell difference was also found (Figure 3, bottom), which is separated from the larger difference polygon. It can be considered as 'noise' of the photo-interpretation, therefore its CLC2000 code can be either forest (311) or transitional woodland (324). These single-cell difference polygons should be automatically eliminated.

4 PROPOSED METHODOLOGY OF HARMONISATION

4.1 ELIMINATION OF CONTRADICTIONS

Several possibilities exist to eliminate contradictions identified between the two CLC-Change databases. These possibilities require different amount of expert involvement (photo-interpretation), consequently different costs.

The most precise, at the same time most complex and time-consuming solution would be to edit the original vector CLC-Change databases at location of mismatches. This option would require the availability of Europe-wide IMAGE1990[1], IMAGE2000 and IMAGE2006 data and preferably other support data (e.g. topographic maps, aerial photos). The process would be very complex as the interpreter would have to take into account all image data and follow generalization rules in both time periods. We judged this option being out of consideration.

An optimized and effective way to handle mismatches is concentrating only on the elimination of the contradictions between year 2000 codes raster versions of CLC-Change databases. (In the description of methodology '$CLC2000_{1990\text{-}2000}$' means the 2000 code in the CLC-Change(1990-2000) database, while '$CLC2000_{2000\text{-}2006}$' refers to the 2000 code in the CLC-Change(2000-2006) database, '$CLC1990_{1990\text{-}2000}$' and '$CLC2006_{2000\text{-}2006}$' mean the 1990 and 2006 codes of the same change databases, respectively). The steps of the proposed methodology are:

1. Use the standard raster (100m) version of European CLC-Change databases at ETRS1989 LAEA projection. Four raster layers can be derived: $CLC1990_{1990\text{-}2000}$, $CLC2000_{1990\text{-}2000}$, $CLC2000_{2000\text{-}2006}$, $CLC2006_{2000\text{-}2006}$;
2. Compare the $CLC2000_{1990\text{-}2000}$ and $CLC2000_{2000\text{-}2006}$ raster layers, create the raster mask of areas where there is disagreement of the 2000 codes;
3. Create the vectorized version the raster CLC-Change layers for the areas of disagreement. This layer will contain four land cover codes as attribute: $CLC1990_{1990\text{-}2000}$, $CLC2000_{1990\text{-}2000}$, $CLC2000_{2000\text{-}2006}$, $CLC2006_{2000\text{-}2006}$.
4. Jump from location to location of contradictions and interpret the valid 2000 code for the area of disagreement. This step will reduce two codes ($CLC2000_{1990\text{-}2000}$ and $CLC2000_{2000\text{-}2006)}$ to a single code.
5. Rasterize the edited vector layer and create a single raster layer containing the 2000 codes to replace the previous two layers ($CLC2000_{1990\text{-}2000}$, $CLC2000_{2000\text{-}2006}$).

The above procedure is relatively simple, and eliminates contradictions between CLC-Change layers and enables the creation of a multi-date CLC change layer. However, this method will not influence mistakes of CLC-Change outside disagreement areas. Moreover, following the elimination of mismatches, change areas smaller than 5 ha might be created (Fig. 1).

4.2 ANALYSING DISAGREEMENTS

The type (thematic content) and size distributions of disagreements are shown in Table 3 for the 30 most frequent disagreement types found between CLC-Change datasets in 24 countries. Table 4 shows the 10 most frequent single-cell (100x100 meter) disagreement types.

[1] Not available in EEA archives

Table 3 List of 30 most frequent disagreements between two CLC-Change datasets (24 countries)

CLC-Change(1990-2000) / CLC-Change(2000-2006)	Number of occurrences	Sum area (ha)	Average size (ha)	Remarks
324-312 / 324-312	1291	11522	8.9	
312-324 / 312-324	930	4533	4.9	
311-324 / 311-324	532	2403	4.5	
324-311 / 324-311	408	3010	7.4	
211-231 / 211-231	159	3255	20.5	Larger average size reflects the subjectivity / un-certainty of separating 211 and 231
211-112 / 133-112	132	1522	11.5	
313-324 / 313-324	109	409	3.8	Small average size means slight differences in delineation of neighbouring polygons
324-313 / 324-312	97	634	6.5	
242-112 / 133-112	74	649	8.8	
324-312 / 311-324	71	1328	18.7	
324-313 / 312-324	67	400	6.0	
324-312 / 324-313	66	369	5.6	
231-112 / 231-112	64	132	2.1	Small average size means slight differences in delineation of neighbouring polygons
313-324 / 312-324	64	410	6.4	
412-324 / 312-324	63	138	2.2	Small average size means slight differences in delineation of neighbouring polygons
312-324 / 412-324	56	1367	24.4	Larger average size reflects the subjectivity / un-certainty of separating 324 and 412
412-312 / 324-312	51	1287	25.2	Larger average size reflects the subjectivity / un-certainty of separating 312 and 324
211-121 / 133-121	49	556	11.3	
311-324 / 321-324	49	3943	80.5	Very large average size means mistake in distinguishing 324 and 321
312-324 / 313-324	49	476	9.7	
324-312 / 313-324	44	233	5.3	
412-324 / 412-324	44	345	7.8	
324-313 / 311-324	41	293	7.1	
211-324 / 311-324	38	510	13.4	
313-324 / 311-324	34	132	3.9	
335-332 / 335-332	34	57	1.7	
323-324 / 323-324	33	1083	32.8	Large average size means mistake in distinguishing 324 and 323
231-112 / 133-112	32	229	7.2	
324-313 / 324-311	32	235	7.3	
324-313 / 324-313	32	337	10.5	

Table 4: List of 10 most frequent single-pixel-size disagreements between two CLC-Change datasets (24 countries)

CLC-Change(1990-2000) / CLC-Change(2000-2006)	Number of occurrences	Sum area (ha)	Interpretation/ Proposed solution for CLC2000
312 - 324 / 312 - 324	481	481	Coniferous forest or clearcut? "Neighbour" classes. Any of 312 or 324 is correct
324 - 312 / 324 - 312	330	330	Coniferous forest or clearcut? "Neighbour" classes. Any of 312 or 324 is correct
311 - 324 / 311 - 324	314	314	Deciduous forest forest or clearcut? "Neighbour" classes. Any of 312 or 324 is correct
324 - 311 / 324 - 311	166	166	Deciduous forest forest or clearcut? "Neighbour" classes. Any of 312 or 324 is correct
313 - 324 / 313 - 324	57	57	Mixed forest forest or clearcut? "Neighbour" classes. Any of 312 or 324 is correct
211 - 231 / 211 - 231	50	50	Arable land or pasture? "Neighbour" classes. Any of 211 or 231 is correct
412 - 324 / 312 - 324	47	47	Coniferous forest or clearcut? "Neighbour" classes. Any of 312 or 324 is correct
231 - 112 / 231 - 112	40	40	Pasture or residential area? "Non-neighbour" classes.
324 - 313 / 312 - 324	23	23	Mixed forest or coniferous forest? "Neighbour" classes. Any of 313 or 312 is correct
335 - 332 / 335 - 332	22	22	Glacier of Bare rock? "Diffuse" boundary. Any of 335 or 332 is correct

Based on Tables 3 and 4 and Figures 1-3, the following conclusions can be drawn:

- Disagreements are result of combined effect of obvious positional inaccuracies in delineation, slight uncertainties in application of CLC nomenclature and mistakes in interpretation
- Largest number of mismatches was found between forestry classes (Tables 3 and 4). This is in line with the fact that most of CLC changes happened among forestry classes.
- Two typical cases of disagreement were found: (1) CLC change continuing in time on the same area: e.g. 211-133 between 1990 and 2000 (Fig. 2); while 133-112 between 2000 and 2006. (2) CLC change continued in the neighbourhood: 324-311 between 1990 and 2000 and the same change in the neighbourhood between 2000 and 2006 (Fig. 3).
- Small average polygon size in a disagreement type most likely means slight differences in delineation of neighbouring changes (Fig. 3).
- Large average polygon size in disagreement type most likely means interpretation mistake made either in CLC2000 or in CLC2006 projects. Two such cases were found (Table 3): distinguishing between 324 and 321, and between 324 and 323.
- Contradictions present at isolated 100x100m cell areas are mostly caused by slight uncertainty in delineation of changes. Analysis of the 10 most frequent single pixel disagreements show that in 9 cases the disagreement included

"neighbouring" classes (i.e. thematically similar class pairs such as 324/312, 324/311, 324/313, 211/231) Only in one case (112/231) did the disagreement include "non-neighbour" classes, i.e. classes belonging to different level-1 class. Consequently, single-pixel disagreements are proposed to be removed by an automated method.

5 TESTING THE METHODOLOGY

An experimental software tool has been developed under ArcInfo AML macro language to support the correction with the following functions:

- Identify disagreements;
- Jump to the next location of disagreement;
- Display corresponding IMAGE2000 image and codes in CLC-Change data;
- Provide an easy to use tool for editing CLC2000 code of CLC-Change databases;
- Display Google Earth imagery.

In Hungary altogether 5 943 ha is affected by contradictions of CLC-Change databases. This area is made up of 1 045 polygons, which have to be examined and the CLC2000 code edited. The methodology was tested on a selected area (560 000 ha) around Budapest.

According to test results, most of contradictions can be resolved by using only IMAGE2000 data. An average 30 seconds were needed for an experienced photo-interpreter to understand the reason of contradiction and decide on the single CLC2000 code. However, in case of more complex contradictions about 2 minutes were needed to find a solution (including checking Google Earth imagery).

Based on the above experience, assigning 1 minute to 1 polygon the estimated workload of the photo-interpretation-based correction of all contradicting polygons is about 2 man-days for Hungary.

467 of these polygons are isolated 100x100m cell areas. If these cells are processed by automatic way, the photo-interpretation-based correction of the remaining 578 polygons would take less than 1.5 man-days for Hungary.

6 ESTIMATED WORKLOAD FOR EUROPE

Estimation has been made for completing the correction for countries listed in Table 2. This list will however increase, as UK and TR will join the list of countries having CLC-Change(1990-2000) as well as CLC-Change(2000-2006) datasets.

Altogether 93 077 ha (931 km^2) area shows contradiction in the CLC-Change databases. This area is made up of 9 471 polygons, including 3 475 isolated 100x100m cell areas.

Based on experience obtained for the test area in Hungary, the estimated workload of the full photo-interpretation-based correction of these polygons is around 22 man-days for Europe. If the 3 475 single-cell isolated polygons are processed in an automatic way, the photo-interpretation-based correction of 5 996 polygons would need around 14 man-days.

7 RECOMMENDATIONS: TO REDUCE DISAGREEMENTS IN FUTURE CLC CHANGE MAPPING

To reduce similar mismatches in future CLC change mapping, the previous CLC-Change dataset has to be considered in the implementation of the update. The next update is CLC2012 under GIO, where thus CLC-Change(2000-2006) should be taken into account.

It means that CLC-Change(2000-2006) has to be displayed as ancillary data on the editing screen while photo-interpreting changes between 2006 and 2012. This way the interpreter can take into account previous change data while deciding and delineating the new change area and providing the attributes. Contradictions cannot be fully eliminated, because of inherent geometric uncertainty of delineation and possible mistakes in CLC-Change(2000-2006) data. However, "continuous" changes (e.g. 211-133, 133-112), will be better harmonised and thematic uncertainties (eg. 323/324) will be reduced.

Upon completing the new update, it is recommended to apply an automated control to highlight areas that are in contradiction with previous CLC-Change data.

8 SUMMARY

There is a certain number of contradiction cases between the currently available two CLC-Change datasets: CLC-Change(1990-2000) and CLC-Change(2000-2006). These contradictions are identified by finding the areas where CLC2000 codes of the two CLC-Change datasets are in disagreement.

Disagreement is the combined effect of obvious positional inaccuracies in delineation of CLC change polygons, slight uncertainties in application of CLC nomenclature and thematic (interpretation) mistakes.

The extent of the problem is small, as only about 1% of all CLC-Change area in Europe is affected.

A simple solution is proposed in order to eliminate contradictions, namely assigning a single CLC2000 code for the problematic areas. CLC-Change data are handled in 100m raster format. A software support for correction has been developed in ArcInfo. If the single cell areas (100x100 m) are eliminated automatically, all CLC-Change data in Europe can be corrected in about 14 days (UK and TR are not considered in the estimation).

9 REFERENCES

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