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CORINE LAND COVER DATABASE OF THE NETHERLANDS: MONITORING LAND COVER CHANGES BETWEEN 1986 AND 2000

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ABSTRACT

This paper describes the methodology for updating the CORINE 1986 database for the Netherlands to CLC2000 and the accuracy of the resulting database. The methodology consisted of computer-assisted visual interpretation of satellite images. Furthermore, topographic maps (analogue and digital), aerial photographs and the national land cover database of the Netherlands (LGN4) were used as additional information in the interpretation and verification processes. During the first step, the geometry and thematic contents of the CORINE 1986 land cover interpretation were revised. Next, the CORINE 1986 was updated on the basis of Landsat 7 ETM images of 1999 and 2000. Land cover changes larger than 5 ha were digitized into the database and labeled to ensure that the land cover changes could be discriminated from other changes in the database. Furthermore, each polygon has an attribute label for the land cover class in 1986 as well as 2000. This procedure ensured consistency between the three databases, because the CORINE 1986 classification, the CORINE 2000 classification as well as the land cover changes could be generated from the same database. The validation was based on a stratified random sample whose true land cover types were taken from aerial photographs. The validation revealed an overall accuracy of nearly 95% for the CLC2000 database (level 3) when taking into account that patches smaller than 25 hectares are not allowed in the CLC database. Omitting this condition reduces the accuracy by 30%. The changes in the CLCchange database have a user and producer's accuracy of 76.1 and 91.1%. The producer's accuracy indicates an overestimation of changes of almost 10%. Comparing the number of changes with the Dutch National database also suggests a slight overestimation of changes.

Keywords: CLC2000, land cover change, Netherlands, Landsat TM

INTRODUCTION

Environmental protection became a major concern and challenge of the European Community. The European Commission (EC) needed good quality information on the state of the environment and natural resources to ensure an efficient implementation of European community policy. It was against this background that the CORINE (COoRdination of INformation on the Environment) programme was initiated by the European Commission (EC). Under the umbrella of this programme a land cover database (CLC90) was created on the basis of a common methodology and with a harmonized nomenclature.

Land cover is changing rapidly in many parts of Europe, particularly in areas with a high population density. Knowledge about these land cover changes is important for spatial planning, resource evaluation, ecological modelling etc. Furthermore, spatio-temporal models that describe and predict land cover changes due to social and economic processes require reliable information on land cover changes in order to calibrate and validate these models (1). Remote sensing data have been recognized as an important source of information for detecting land cover changes. Differences in surface reflectance derived from multi-temporal overpasses of airborne or spaceborne sensors can be related to changes in land cover. Moreover, land cover classes can be discerned using remotely sensed images and therefore the type of change can be detected.

This paper presents some of the first results of the CLC2000 project and will describe (i) the methodology that was used/developed for updating the CORINE land cover database of The

Netherlands; (ii) the classification accuracy of the CLC2000 land cover database; (iii) the classification accuracy of the land cover changes database and the comparison of the results for the Dutch CLC2000 project with the national land cover database LGN4.

DATA AND METHODS

For improving the Dutch CLC86 database Landsat TM5 images were used that had been recorded in July 1986 and August 1988. For updating the CLC86 towards CLC2000 Landsat TM7 images were used that had been recorded in July 1999 and August 2000. All images were geometrically corrected using ground control points obtained from the digital 1:10,000 vector database of the Netherlands and warped to the Dutch geometric system using a second degree polynomial transformation with cubic convolution resampling. Geometric accuracy of the Landsat TM5 images and Landsat TM7 images was approximately 50 and 25 meters.

The Dutch land use database (LGN) is a grid database with a cell size of 25 meters (2). The four versions (LGN1–4) are based on Landsat TM recordings of 1986, 1992/1994, 1995/1997 and 1999/2000. LGN1 was used for validation purposes (CLC86rev), LGN4 was used for land use classification and validation purposes.

The Netherlands Topographic Service (TDN) produces the 1:10,000 digital topographic map of the Netherlands (further to be mentioned 'TOP10-vector'). The nomenclature of the TOP10-vector consists of a few hundred entities, which are related to polygon, line and point features. Since 1998, the entire Netherlands have been covered by around 1,350 map sheets, which cover an area of 5 km by 6.25 km each. The 1:10,000 digital topographic map mainly contains information on land cover. The functional use of many classes can only be determined by contextual information, e.g. grassland and forest located in urban areas (parks or sport grounds).

The CBS database contains mainly information on functional land use classes (for example industrial/commercial areas and recreational facilities) and is produced every 3 or 4 years by theCentral Bureau of Statistics (CBS). The CBS databases of 1989 and 1996 were used for validation purposes.

True colour aerial photographs were mainly used for the validation process. These photographs cover the Netherlands at a resolution of 0.5 meter. They were acquired in May/July 2000.

The LaCoast database (3) and the hardcopy topographical map 1: 50,000 (1986) were used for the revision of CLC86. The digital geomorphological map of the Netherlands and Top50Vector were used to delineate some specific land cover classes.

Database production

The production of Dutch CLC2000 database was carried out in two steps. In the first step the CLC90 database was revised using satellite images of 1986 – 1988 and old ancillary data. During this step thematic and geometric errors were corrected in order to avoid the overestimation of land cover changes. These corrections were necessary, because the CLC86 was produced in 1988 by visual interpretation of hardcopy satellite images and delineation of the different land cover classes using lines drawn on transparencies. The subsequent digitisation of the lines on these transparencies using a digitising table caused errors which can be avoided using on-screen digitising. Moreover, the Netherlands were split into working areas during production of the original CLC86. As a result, the connection of continuous boundaries at the edges of the different working areas sometimes gave problems which could now be corrected.

The revised CLC86 (CLC86rev) was updated in the second step. During this process, the CLC86rev database was displayed on the computer display with the Landsat TM7 imagery (2000) on the background. In a second display, a copy of the CLC86rev database was displayed with the Landsat TM5 imagery on the background (1986). Land cover changes that were interpreted from the Landsat imagery were coded directly into the CLC86rev database by adding boundaries and adding the new CLC2000 attribute to a dedicated polygon attribute. This process was supported by some dedicated ARC/INFO routines which handled polygon closure and attribute assignment.

Note that this procedure results in a database which contains polygons smaller than the CORINE limit of 25 hectares. An urban expansion into the surrounding agricultural area of 10 hectares will result in a 10-hectare polygon which has an attribute defining it as “agriculture” in 1986, but as “urban” in 2000. However, this database can be converted in the CLC2000 or into CLC86rev by applying a dissolve operation to one of the two attributes. This operation will either add the polygon to the urban area or to the agricultural area thereby fixing the problem. Moreover, CLCchange (the changes database) can be generated directly from the database by selecting all polygons where the value of the attribute defining the land cover type in 1986 does not equal the value of the attribute defining the land cover type in 2000. Therefore, one of the methodological conditions set by the European Environmental Agency, i.e. that the intersection of CLC2000 and CLC86rev will result in CLCchange, can be fulfilled.

Validation

A validation was carried out to define the classification results for the Dutch CLC2000 and CLCchange databases. For each CLC2000 land cover class 62 sample points were selected in a stratified, random way. The number of points was calculated using the binomial distribution (4) and assuming an a-priori thematic accuracy of 80% and a reliability of 90%. For each of these points the attributed CLC2000 land cover class was compared with the “real” CORINE land cover. The “real” land cover was obtained by using colour aerial photographs and Land Use Statistics of 1996 (CBS96). To a minor extent also the digital topographical map 1:10,000 (Top10Vector) and Land Use database for the Netherlands (LGN4) were used as reference datasets.

The CLCchange database was validated by 100 “non-changed” and 500 “changed” sample points that were randomly selected. The “real” land cover was determined for 1986 and 2000. The CBS89 and LGN1 databases were used as reference databases to obtain the 1986 land cover. Comparison of “real” land cover for 1986 and 2000 made it possible to validate the CLCchange. Changes and CLCclasses were corrected for the area they were occupying in the databases CLC2000 and CLCchange.

The classification results were tabulated in so-called confusion matrices. For each land cover class the percentages of correctly and incorrectly classified sample points were determined. The user’s accuracy and producer’s accuracy of each CLC class were determined and corrected for the map category proportion (5). The user accuracy of the classification was defined as the probability that the “real” land cover would be classified in accordance with the land cover class in the CLC2000 database. The producer accuracy of the classification was defined as the probability that a certain land cover class of the CLC2000 database would agree with the “real” land cover. The total classification accuracy will outline the total thematic accuracy of the CLC2000 database. The total accuracy was defined as the total number of points which were classified correctly for all classes divided by the total number of sample points (6).

The validation of CLC2000 was carried out in two ways: (i) CLC method: the “real” land cover was obtained from reference databases taking into account the specifications set for CLC2000. The land cover for a sample point must belong to a contiguous area of at least 25 hectares, a maximum boundary displacement of 100m or fit into the CLC class definitions. (ii) Point method: Only the “real” land cover at a sample point was determined from the reference databases. The surroundings of the sample point were not taken into account to attribute a CLC class to the reference point. This approach allows us to quantify the effect of the CLC mapping conditions on the accuracy of the database.

RESULTS

The Netherlands are characterized by thirty out of 44 CORINE land cover classes. Almost ¾ of the Netherlands is classified as agricultural land. Pastures (231), arable land (211) and complex cultivation patterns (242) are the most extended land cover types. Land classified as artificial areas or as semi-natural and forest areas occupy around 10% of the Dutch territory each. The remainder of the Dutch land surface is classified as wetland or as water bodies, rivers and channels (7).

Between 1986 and 2000 around 4.76% (1,685 km^2) of the Dutch land surface changed its land cover. Table 1 shows the land cover changes at CORINE level 2. The most prominent land cover change is the conversion of agricultural land into artificial areas (112, 121, 133, 142). The change of pastures into arable land (green houses) within the class agricultural land is a typical change in the period 1986 – 2000. Other important changes are the conversion of agricultural land into deciduous forest, natural grassland and inland marshes (7).

Table 1. Land cover changes in the Netherlands between 1986 and 2000 (CORINE level 2) (km^2).

		CLC2000															
		11	12	13	14	21	22	23	24	31	32	33	41	42	51	52	total
CLC1986	11	0,0	6,7	0,0	0,4	0,0	0,0	0,0	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	7,4
	12	0,2	0,0	2,2	0,0	0,4	0,0	0,1	0,0	0,0	0,3	0,0	0,2	0,4	0,3	0,1	4,2
	13	36,7	47,2	0,3	3,4	2,3	0,0	0,0	0,2	1,9	7,4	0,0	2,3	0,0	3,5	0,5	105,9
	14	5,9	1,6	0,3	0,2	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,3	0,0	8,7
	21	112,5	65,9	38,4	40,3	0,0	9,9	18,6	23,4	58,9	37,3	0,3	12,6	0,0	7,5	0,4	426,1
	22	2,0	0,7	0,1	1,3	2,7	0,0	0,0	0,3	0,3	0,0	0,0	0,6	0,0	0,1	0,0	8,2
	23	175,8	80,7	45,3	42,8	203,3	3,4	0,0	45,7	23,9	13,9	0,9	25,4	6,2	15,6	0,0	682,9
	24	111,7	58,1	14,8	23,5	13,0	0,3	0,2	1,2	9,4	5,0	0,0	0,0	0,0	8,8	0,0	246,0
	31	2,8	3,5	3,2	8,9	0,8	0,0	0,8	1,3	0,4	9,8	0,0	0,0	0,0	1,1	0,0	32,6
	32	0,1	2,5	1,6	1,3	0,0	0,0	0,0	0,0	12,1	0,0	0,0	0,8	0,0	0,7	0,0	19,1
	33	0,6	0,7	1,0	0,5	0,0	0,0	0,0	0,0	0,0	3,8	0,0	0,0	20,0	0,6	11,6	38,7
	41	0,2	0,0	0,8	1,6	1,1	0,0	0,2	1,5	6,0	0,0	0,0	0,0	0,0	0,3	0,0	11,6
	42	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	14,5	10,4	6,3	1,4	12,7	7,2	52,5
	51	0,4	1,6	6,2	0,3	2,4	0,0	0,2	0,3	0,0	0,2	0,0	6,8	0,0	0,3	0,0	18,6
	52	0,0	0,1	1,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	4,8	0,0	14,1	2,0	0,0	22,6
	total	448,9	269,4	115,8	124,7	225,9	13,6	20,1	74,0	113,3	92,3	16,4	55,1	42,0	53,8	19,8	1685,1

Producer's & user's accuracy of CLC2000 and CLCchange

The thematic accuracy at level 2 for the CLC2000 database is almost 96%. All level 2 classes have user accuracies above 70%. The total thematic accuracy of the CLC2000 database at level 3 is almost 95%. Only a few classes (132, 141, 142, 243, 313 and 324) that occupy only small tracts of land, have a relatively low user accuracy (see (7)). An explanation for their relatively low accuracy (40 – 80%) is that they are mixed classes or represent land use instead of land cover. In Table 2 the user's accuracy and producer's accuracy for the CLC and point method are visualized. The user and producer accuracy are much lower when excluding the conditions set for CLC2000 in obtaining the "real" land use (point method). The total thematic accuracy dropped by 30% when omitting land cover information of the surroundings of the sample points.

The CLCchange database has a producer's accuracy of 91.2%. However, the user accuracy is low (76.1%). The user and producer accuracy of non-changed land are nearly 100%.

CLC2000 compared with LGN4

Comparison of the CLC2000 database with the Land Use database of the Netherlands (LGN4) is possible after aggregation of classes in both databases. Table 3 shows that almost the same amount of land is occupied by forest for both databases. Land occupied by artificial areas seems to be under-estimated, whereas the surface area occupied by agricultural land is over-estimated in CLC2000. Small villages or isolated urbanization are not classified as artificial areas. They are too small and therefore often classified as agricultural land. Total area covered by water surfaces could not be compared.

The number of changes seems to be slightly overestimated. The area changed is 388.9 km^2 for the period 1995/1997 - 1999/2000 according to our National Land Cover database (LGN4), which is 0,94% of total surface area (8). Extrapolation of the number of changes to the period 1986-2000 suggests an overestimation of changes for CLC2000.

Table 2. Producer & user accuracy of CLC2000 and CLCchange (%)

Land Cover classes	CLC method user	CLC method producer	point method user	point method producer
CLC2000 database				
Urban fabric	94,5	98,4	55,8	72,6
Industrial, commercial and transport units	93,7	93,8	49,7	73,0
Mine, dump & construction sites	88,6	94,8	53,9	76,5
Artificial, non-agricultural areas	70,7	90,8	47,7	76,5
Arable land	95,6	95,2	56,0	79,0
Permanent crops	100	91,9	16,7	66,1
Pastures	99,1	91,9	61,7	66,1
Heterogeneous agricultural areas	87,2	95,7		
Forests	99,4	96,7	71,4	78,8
Scrub&/or other herbaceous vegetation	97,7	95,3	80,9	81,5
Open spaces with little or no vegetation	96,0	93,5	80,4	79,0
Inland wetlands	99,2	90,3	58,6	66,1
Maritime wetlands	89,3	93,5	78,8	82,3
Inland waters	99,7	100	89,9	99,0
Marine waters	100	100	99,9	100
Overall accuracy	95,8		68,1	
CLCchange database				
change	76,1	91,2		
no change	99,7	99,0		
Overall accuracy	98,7			

Table 3. Comparison of class areas in LGN4 and CLC2000 (km^2).

	LGN4 Area	Changes 1995/97 - 99/00	CLC2000 Area	Changes 1986/88 - 99/00
Urban area	4897,9	199,2	4537,1	958,8
infrastructure	1005	2		
	5902,9	201,2	4537,1	958,8
agriculture	22566,4	44,4	25241,5	333,5
orchards	279	11,7		
greenhouses	134,8	10,3		
	22980,2	66,4	25241,5	333,5
Forest	3118	10,2	3143,1	113,3
nature	1751	88,1	1392	206
Water	7774,9	23	1118,4	73,6
Total	41527	388,9	35432,1	1685,2

* aggregation of 8 LGN monitoring and CLC classes to 5 classes
* CLC2000 data refer to land surface, i.e. class 423, 522,523 and IJsselmeer were not taken into account
* nature area for CLC2000 is calculated as the sum of classes 32, 33, 41 and 42
* water area for CLC2000 are the water bodies and courses with the exclusion of IJsselmeer, sea and ocean and estuaria

CONCLUSIONS

The thematic and geometric contents of CLC86 were revised. Next, the CLC86 was updated on the basis of Landsat TM images of 1999 and 2000. Land cover changes larger than 5 ha were digitised and labeled. Afterwards, the three databases, i.e. CLC86rev, CLC2000 and CLCchange,

could be generated from the same database. The used methodology ensured consistency between the three databases. Finally, the CLC2000 and CLCchange databases were validated. The overall accuracy of CLC2000 is almost 95% which meets the requirement (>85%) set by the European Environment Agency (EEA). The producer's accuracy of 91.2% for the CLCchange database indicates an overestimation of changes of almost 10%. Also the comparison with the National Land Cover database (LGN4) suggests a slight overestimation of changes.

The CLC2000 and CLCchange databases of the Netherlands have a high thematic accuracy. They are a very useful contribution to realise European land cover datasets that can be used in various environmental studies.

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