LAND USE MAPPING AND MONITORING IN THE NETHERLANDS (LGN5)

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ABSTRACT

Land use is changing rapidly in many parts of the world, particularly in areas with high population density as The Netherlands. The effect of these land use changes becomes increasingly important in areas as spatial planning, water and environmental management.

In the Netherlands, information on land use has been available since the beginning of the 1990's from the Land Use Database of The Netherlands (LGN database). With finishing LGN5 a detailed serie of five land use databases (LGN1-5) from 1990's till 2004 is made available for The Netherlands. Land use information is stored in 25*25 m grid cells. The LGN5 dataset is based on satellite imagery from 2003 and 2004 and additional data. The nomenclature of the database includes crop types, forest types, water, various urban classes and several ecological classes.

The availability of several versions of the LGN land use database spurred an interest by users who wanted to compare the LGN versions in order to derive land use changes in the Netherlands. Research on the accuracy of the land use changes derived from the LGN database demonstrated that these changes were overestimated by as much as 100% when comparing the LGN2 and LGN3 databases using GIS overlay techniques. From LGN3 onwards a methodology was designed to monitor land use changes in a consistent and accurate way. From 1995 till 2004, land use changes are monitored for the aggregated classes urban, orchards, greenhouses, agricultural land, water, infrastructure, forest and nature.

This paper presents the methodology used to update the national land use database of The Netherlands. The number (0.67%) and type of land use changes between 2000 and 2004 are described and compared with those changes between 1995 and 2000. The land use changes are validated by assessing the real land use changes from aerial photos and large-scale topographic maps for a sample of almost 800 points that were drawn using stratified random sampling. The results demonstrate that the LGN5 change map has a user's accuracy of 84.5% and a producer's accuracy of nearly 100% when validating at the level of change/no change.

INTRODUCTION

Land use is changing rapidly in many parts of the world, particularly in areas with high population density as The Netherlands. The effect of these land use changes becomes increasingly important in areas as spatial planning, water and environmental management.

Remote sensing data in combination with additional data sources has been recognized as an important source of information for detecting land use changes. However, it is necesarry to mention two difficulties in change detection with remote sensing. First of all, different land use types often have similar spectral properties or external factors (phenology, clouds, soil moisture) severely influence the satellite imagery. Secondly, change detection has to deal with rare phenomenon, i.e. the area of change in five to ten years is relatively small in relation of the total area [1]. Both difficulties make change detection sensitive to external factors.

Land use change detection can be divided into 3 approaches. First, comparison of independent classified images and classification results using GIS overlay techniques. Second, application of change detection algorithm on combined data set of two satellite images. Third, only visual interpretation of changes (CLC approach, see also [2]) in which you have only to deal with small areas.

Main objective of this paper is to present the Dutch land use database (LGN) and show you the way how land use changes are monitored. The large monitoring dataset makes it a unique database to follow land use changes with time. An accuracy assessment has been carried out to validate the change database.

METHODS

Overview

Land use mapping and change detection in The Netherlands is based on satellite imagery in combination with additional data sources. The Dutch land use database (referred as the LGN database) has been developped from an experimental database (LGN1 – 1986) into a widely used database (LGN5 – 2003/2004). The final versions of the LGN database are connected with the Dutch topographical database (TOP10Vector) and between these databases (LGN3 – LGN4 – LGN5) monitoring of land use changes is possible in a reliable way [1]. The LGN database is a grid database with a cell size of 25 meters and it discriminates 39 different land use types. Due to the fragmented nature of urban and ecological classes it is often not possible to derive changes from satellite imagery. Furthermore, the changes in crop type are often not relevant as farmers use crop rotation schemes. Therefore, the 39 land use types are aggregated into 8 main land use classes (agriculture, orchards, greenhouses, forest, water, urban area, infrastructure and nature) to monitor land use changes.

Data

Satellite imagery: Multi-temporal satellite data were used to carry out land use classifications (mainly crop classification). From the year 1999 and 2000 Landsat TM images were used (LGN4). Due to the failure of Landsat 7 and the limited availability of useful images a combination of Landsat ETM7 and TM5, LISS-1c and ERS-SAR images of the years 2003 and 2004 were used for LGN5. The images were georeferenced and cubic convulation was used to resample the images to 25m grid size.

TOP10Vector: The Netherlands Topographic Service (TDN) produces the 1:10.000 digital topographic map of the Netherlands. Since 1998, the entire Netherlands is covered by 1350 map sheets, which cover an area of 5 km to 6.25 km each. The mapsheets are updated every 4 years.

Aerial photographs: Two sets of true-color aerial photographs were used for the validation process. The aerial photographs cover the entire Netherlands at a resolution of 0.5 meter. They were acquired in the years 2000 and 2003.

Agricultural statistics (CBS and BRP): The agricultural statistical data produced by Central Office of Statistics (CBS) for the year 2003 were used to fine-tune the crop classification with the CBS data for their 66 CBS-agricultural areas. Registration of real land use in the Netherlands is organised through the Basic Registration Parcels (BRP) project. 23000 BRP-parcels were used to validate the agricultural crops in LGN5.

Methodology

LGN5-grid database: With a copy of LGN4 database the production of LGN5 database was started. The agricultural classes were aggregated. The TOP10vector classes buildings, tree nurseries, orchards, greenhouses and poplar stands were converted from vector to 25 m grid format and consequently added to the LGN5 database. The addition of TOP10vector classes was in the above mentioned sequence and according to conversion tabels [3]. Land use changes between LGN4 and the newly added TOP10vector data were detected. After all, the update of the LGN database was finished with the detection of land use changes through the visual interpretation of images. Aerial photos and additional databases were used to assist the interpretation.

LGN5-crop database: The production of the crop database was started with the selection of the agricultural area of LGN4 (aggregation of classes). For that area agricultural parcels are taken out of the topographical database TOP10vector, and when needed additional crop boundaries were manually added. A multi-temporal classification of satellite imagery on basis of NDVI was carried out. The differences in phenology for seven agricultural crops was used to classify them (grassland, maize, potato, sugar beet, wheat, other crops and flower bulbs). Mostly, a supervised classification with manual correction was applied. Classification results were compared with the statistical data per CBS agricultural area. With the allocation of a majority crop class to every crop parcel the crop database was finished [4].

Validation

The crop classification was validated for 55 TOP10vector mapsheets. The mapsheets were selected in such a way that a good characterisation of all Dutch agricultural areas was established. A selection of 25% of the BRP parcels within the TOP10vector mapsheets was used as a reference dataset. At pixel level, the level of accordance of both datasets has been established.

The validation of land use changes was carried out by validating a stratified random sample of 400 changed and 384 non-changed points. For all points it has been verified if land use has changed between 2000 and 2003. Aerial photographs were used for this purpose. For those points where land use (non)changes does not match between the reference data and the LGN database, a second verification on basis of satellite images has been carried out. After all, large parts of the LGN4 and LGN5 interpretation was based on satellite imagery of 1999 respectively 2004 that can contribute to the mismatch between the reference dataset and the LGN database.

For both validations, the reference points were tabulated in a so-called confusion matrix. User and producer accuracies were calculated [5]. The validation results of the change database were corrected for the large differences in map proportion between the changed and the non-changed areas [6].

RESULTS & DISCUSSION

Land use changes

Land use changes between different versions of LGN can be monitored for the 8 monitoring classes (agriculture, orchards, greenhouses, forest, water, urban area, infrastructure and nature). Totally, an area of 27764 ha (or 0.67%) has changed its land use between LGN4 (1999/2000) and LGN5 (2003/2004). Major land use changes are the decrease of agricultural area (23.919 ha) and increase of urban areas (15.346 ha). The internal dynamics in the classes greenhouses and orchards are relatively high with +9.0% and -3.6% respectively +5.3% and -2.3% (table 1). More than 50% of all changes are land use changes from agricultural areas into urban areas. Also the change of agricultural area into nature is important (15.8%). All other type of changes are below 5.5% or even below 2.5% for the changes from non-agricultural areas to another land monitoring class (table 2).

Table 1. Land use changes between LGN4 and LGN5 for 8 monitoring classes.

	Area (ha) LGN4	Changes (increase in ha)	Changes (increase in %)	Changes (decrease in ha)	Changes (decrease in %)	Diff. (ha)	Diff. (%)
Agricultural area	2256640	622	0.03	23919	1.06	-23297	-1.03
Greenhouses	13483	1218	9.03	479	3.55	739	5.48
Orchards	27901	1483	5.32	632	2.27	851	3.05
Forest	311799	737	0.24	844	0.27	-107	-0.03
Water	777493	2228	0.29	690	0.09	1538	0.20
Urban area	489787	15346	3.13	329	0.07	15017	3.07
Infrastructure	100503	1055	1.05	5	0.00	1050	1.04
Nature	175102	5074	2.90	866	0.49	4208	2.40
Total	4152708	27764	0.67	27764	0.67	0	0.00

Table 2. Type of land use change between LGN4 and LGN5 as percentage of the total change area.

LGN4 \ LGN5	Agricultural area	Green houses	Orchards	Forest	Water	Urban area	Infra-structure	Nature	Total
Agricultural area	0.00	4.28	5.22	2.39	4.63	50.56	3.31	15.76	86.15
Greenhouses	0.25	0.00	0.00	0.00	0.02	1.41	0.03	0.00	1.73
Orchards	1.41	0.08	0.00	0.01	0.01	0.67	0.09	0.00	2.28
Forest	0.20	0.00	0.10	0.00	0.11	1.03	0.13	1.48	3.04
Water	0.08	0.00	0.00	0.07	0.00	1.35	0.06	0.92	2.48
Urban area	0.02	0.02	0.00	0.00	0.89	0.00	0.16	0.11	1.19
Infrastructure	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.02
Nature	0.28	0.00	0.02	0.18	2.36	0.24	0.03	0.00	3.12
Total	2.24	4.39	5.34	2.65	8.03	55.27	3.80	18.28	100.00

Land use changes between LGN3 and LGN4 are slightly higher with 38.879 ha (0.94%). The main changes are also the decrease in agricultural land (31.725 ha) and the increase in urban area (19.919 ha) [1]+[3]. Almost 50% of all changes are land use changes from agricultural areas into urban areas. More than 20% of all changes are from agricultural areas into nature areas. Another important change is the change of orchards into agricultural areas (table 3). Also, the changes from non-agricultural areas into another monitoring class are only taking a small proportion of the total land use changes (<2%).

Table 3. Type of land use change between LGN3 and LGN4 as percentage of the total change area.

LGN3 \ LGN4	Agricultural area	Green-houses	Orchards	Forest	Water	Urban area	Infra-structure	Nature	Total
Agricultural area	0.00	2.59	3.00	2.35	3.96	47.61	0.42	21.66	81.60
Greenhouses	0.31	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.99
Orchards	10.69	0.06	0.00	0.22	0.04	0.87	0.00	0.05	11.93
Forest	0.16	0.01	0.00	0.00	0.16	0.54	0.01	0.30	1.18
Water	0.00	0.00	0.00	0.00	0.00	1.23	0.02	0.13	1.37
Urban area	0.23	0.00	0.00	0.03	1.23	0.00	0.06	0.53	2.08
Infrastructure	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.04
Nature	0.01	0.00	0.00	0.01	0.50	0.30	0.00	0.00	0.82
Total	11.41	2.66	3.00	2.61	5.91	51.23	0.51	22.67	100.00

Table 4 shows that the area occupied by agricultural land and orchards is decreasing in the Netherlands for the last 10 years. The area of greenhouses is steadily increasing, however, within a LGN update cycle relatively large areas are also converted from green houses into other land uses (see table 2 and 3). The area under orchards decreased heavily in the LGN3-4 cycle. In the last update cycle the total area under orchards recovered slightly. The internal dynamics are like those for greenhouses. The total area under forest is increasing which is in contradiction with the changes monitored (table 1). A small increase in area under infrastructure, mainly due to the construction of some large infrastructural projects in the Netherlands from 2001 onwards (HSL, Betuwe-lijn). As indicated above, the large increase of area under urban and nature can also be noted from table 4.

Table 4. Area of monitoring classes per LGN version and differences between versions (in ha).

	LGN3 1995/1997	LGN4 1999/2000	LGN5 2003/2004	LGN4-3	LGN5-4	LGN5-3
Agricultural area	2300520	2256640	2223310	-43880	-33330	-77210
Greenhouses	12816	13483	15252	667	1769	2436
Orchards	32167	27901	29166	-4266	1265	-3001
Forest	306369	311799	315672	5430	3873	9303
Water	774805	777493	777141	2688	-352	2336
Urban area	465484	489787	508289	24303	18502	42805
Infrastructure	100094	100503	101763	409	1260	1669
Nature	160451	175102	182083	14651	6981	21632

Accuracy

The validation of the agricultural crops resulted in an overall accuracy of 80.5%. The validation was based on more than 86000 pixels distributed over 23000 crop parcels. The drop in classification accuracy per crop type varies between 0-25% (figure 1). The overall accuracy has dropped with 10% compared to the LGN4 database due to the limited availability of useful satellite imagery for the crop classification.

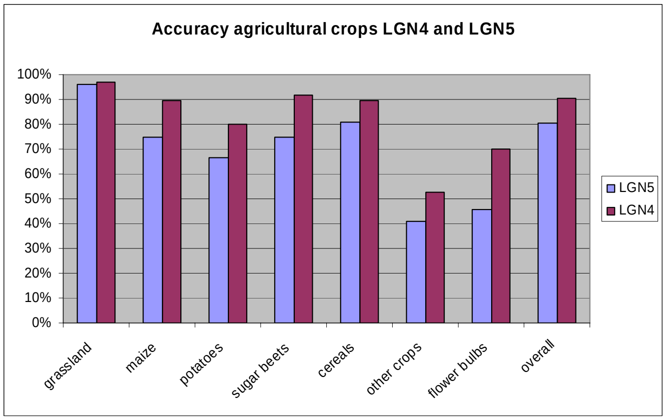

Figure 1. A comparison of the accuracy of the crop classification between LGN4 and LGN5.

Within the strata "changed" 62 out of the 400 random selected points was wrongful classified as a land use change. The points selected in the strata "unchanged" were all correctly classified. After correction for the map proportion it appeared that 15% of all changes were inaccurately classified.

CONCLUSIONS

An overlay of different versions of LGN will result in more differences as the changes monitored by the used method. Corrections implemented in an LGN version, crop rotations or geometric inaccuracies can be accounted for these differences. Research on the accuracy of the land use changes derived from the LGN database demonstrated that land use changes were overestimated by as much as 100% when comparing the LGN2 and LGN3 databases using GIS overlay techniques [7]. From LGN3 onwards a methodology was designed to monitor land use changes in a consistent and accurate way. Land use classes are monitored for the land use classes, agricultural area, greenhouses, orchards, forest, water, urban area, nature and infrastructure. Discrepancies between changed areas (table1) and differences in areas between LGN versions (table 4) can be explained by one or a combination of these factors.

Most important land use changes in The Netherlands for the last 10 years are the increase of urban and nature areas at the expense of agricultural land. Internal dynamics within the classes greenhouses and orchards are large.

The accuracy of the crop classification dropped due to the limited availability of satellite imagery. The validation of the change database showed that the changes are relatively well detected. However, it is needed to improve the change detection as it is only possible to monitor them for aggregated classes.

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