Land use mapping and monitoring in the Netherlands using remote sensing data

A.J.W. de Wit

Centre Geo-information
Wageningen University and Research Centre
Wageningen, The Netherlands
Allard.dewit@wur.nl

Abstract—**A database with land use change in The Netherlands was created using visual interpretation of Landsat TM imagery. The real land use changes were separated from other changes in the database by storing the real changes in a separate binary mask with code "1" representing "change" and code "0" representing "no-change". The database was validated using a stratified random sample of 394 points. The change database has a producer's accuracy of 0.759. However, the current methodologies for validating a change database are not perfect and further research is necessary for proper validation.**

Keywords-land use; change detection; monitoring; Landsat TM; validation

I. INTRODUCTION

Land cover is changing rapidly in many parts of the world, particularly in areas with a high population density. The effect of these land cover changes becomes increasingly important for diverse applications as spatial planning, resource evaluation and ecological modeling. Furthermore, spatio-temporal models that describe and predict land cover change because of sociological and economic processes need reliable information on land cover changes in order to calibrate and validate these models [1].

Remote sensing data has been recognized as an important source of information for detecting land cover changes, however, it must also be recognized that the application of remote sensing change detection techniques is plagued with difficulties and failures [2]. There are two main reasons for these difficulties. First off all, it is assumed that a change in land cover results in a change in reflectance ([3],[4]). However, different land cover types often have similar spectral properties or external factors (phenology, solar illumination, clouds, soil moisture) severely influence the satellite imagery. The second reason is the fact that on timescales of five to ten years the total area where land cover changes are occuring is often small. With land cover change detection we are thus trying to monitor a "rare phenomenon" from a statistical point of view. This makes change detection extremely sensitive to external factors.

Remote sensing change detection techniques can be roughly divided into two approaches [3]. First, two satellite images from different dates can be classified independent from each other and the classification results can be compared using a GIS overlay technique. Second, a change detection algorithm can be applied to a combined data set of two satellite images in order to extract the land cover changes directly from the satellite measured reflectance. The advantage of the first approach is that it provides insight in the change relationships, but a misclassification in either classification will directly result in a false land cover change. The difficulty with the second approach is that usually some threshold has to be choosen in order to separate real land cover changes from no change. The choice of this threshold is rather subjective, although techniques have been developed that optimise the chosen threshold [5]. Furthermore, there is no consensus on the type of change detection algorithm that performs best. In a case study described by [3] image regression is reported to provide the most accurate change detection result. Bruzzone and Serpico [6] report that their iterative change detection algorithm outperforms post-classification comparison, while [4] obtained similar change detection accuracy using post-classification comparison.

The limitations of automated change detection techniques demonstrate that other methods have to be explored in order to derive accurate change detection results. Despite the difficulty of automated land cover change detection, many land cover changes can be be recognised easily by visual interpretation of satellite images. Although this may seem laborious at first, it should be realised that many countries already have land cover mapping projects where visual interpretation of satellite imagery plays an important role. Furthermore, the fact that land cover changes are a "rare phenomenon" means that updating a land cover database will involve considerably less work compared to reclassifying the entire area.

II. DATA AND METHODOLOGY

A. Overview

The methodology described below was developed within the framework of the Dutch land use database (further to be mentioned "LGN database"). This project started in 1988 [7] and aimed at the development of a national land use database in order to provide accurate and timely information on land use at national and regional scales. The LGN database is a grid database with a cell size of 25 meters and it discriminates various land use types (urban area, forests, water, several crop types and natural areas). Today there are four versions of the LGN database (LGN1..LGN4) based on Landsat TM observations of 1986, 1992/1994, 1995/1997 and 1999/2000.

When early LGN versions (LGN1-LGN3) were compared for land use changes, it became clear that the database grossly overestimates the total area of land use changes [8]. The reason was that the updating methodology was not designed for land use monitoring and did not

differentiate between true land use changes and other changes (corrected mis-interpretations, geometrical errors, etc.) in the LGN database. With the updating of the LGN3 database towards LGN4 it was clear that a new methodology was necessary in order to incorporate land use changes in the database in a reliable way. This paper presents the methodology that was developed for mapping land use changes and the results.

B. Data

Satellite imagery: Multi-temporal satellite data were used to carry out the land use classification and perform the change detection. The "old" satellite imagery consisted of a series of Landsat TM images that were recorded in 1995 and 1997 for the Western and Eastern part of The Netherlands. The "new" satellite imagery consisted of a series of Landsat TM images that were recorded in 1999 and 2000 for the Western and Eastern part of The Netherlands. All satellite images were registered to the Dutch reference system using ground control points obtained from TOP10-vector. Cubic convolution resampling was applied to resample the satellite data to the 25 meter LGN grid.

TOP10-vector: The Netherlands Topographic Service (TDN) produces the 1:10.000 digital topographic map of the Netherlands (further to be mentioned "TOP10-vector"). Since 1998, the entire Netherlands is covered by around 1350 map sheets, which cover an area of 5 km to 6.25 km each.

Aerial photographs: True-color aerial photographs were used for validation purposes. These photographs cover the entire Netherlands at a resolution of 0.5 meter and were acquired in May 2000.

C. Description of the methodology

The nomenclature of the LGN4 database contains 39 classes including urban area, forest types, water, crop types and several ecological classes. With regard to monitoring of land use it was clear that monitoring could not be implemented for all 39 classes. Due to the fragmented nature of urban and natural classes, it is often not possible to derive changes in these classes from Landsat TM imagery. Furthermore, the changes in crop type are often not relevant because many farmers use a crop rotation scheme, so changes in crop type will reflect the rotation scheme rather than real land use changes. Therefore, we decided to limit the monitoring of land use by aggregating the 39 classes into eight "main land use classes:" Agriculture, orchards, greenhouses, forest, water, urban area, infrastructure and nature.

The actual updating of the database was carried out in a two-step updating process. During the first step of the process, the LGN3 database was updated with only real land use changes. In practice, this was carried out by having 3 image viewers on a computer display simultaneously. The left viewer contained an "old" satellite image (usually an image of July or August), the right viewer contained a "new" satellite image and the middle viewer contained a "new" satellite image overlayed with the LGN database. In the middle viewer the agricultural classes were made transparent so that the satellite image viewed in the background. The transparency was applied because most of the land use changes that occur in the Netherlands are the conversion of agricultural land to urban area, water, nature or forest. Having the agricultural classes made transparent thus facilitates interpretation and digitising.

The result of this first step is a pre-LGN4 database that contains all land use changes that have occured between 1995/1997 (LGN3) and 1999/2000 (LGN4). The differences between LGN3 and pre-LGN4 thus reflect the real land use changes because no other updates or fixes have been applied to the database. Both the LGN3 and pre-LGN4 database were aggregated to the 8 "main land use classes." The differences between LGN3 and pre-LGN4 were stored in a binary mask that was created by pixel-wise comparison of the aggregated LGN3 and pre-LGN4 database. During this process, all pixels that had different values in the LGN3 and pre-LGN4 database were assigned value "1" while all other pixels were assigned value "0".

During step 2 the pre-LGN4 database was checked and changes were applied that fixed previous mis-interpretations, geometrical errors or other changes that were necessary to apply but which were not changes in land use. However, due to the existence of the binary change mask, these fixes in the database can be separated from the real changes in land use.

D. Validation

Validation of the land use changes was carried out by validating a stratified random sample of 394 points. Respectively 74 and 320 points were randomly chosen in the areas that were marked in the LGN4 database as "no-change" and "change." The number of points was calculated using the binomial distribution [9] and assuming an a-priori accuracy for the change and no-change classes of 0.7 and 0.95. The reference points were tabulated in a confusion matrix which was corrected for the large difference in map proportion of the change class (0.94%) and the no-change class (99.06%) using a method described by [10].

In order to determine the "old" land use, we used old versions of TOP10-vector. We allowed some deviation in acquisition date, because the total area where the acquisition date of TOP10-vector corresponded with the acquisition date of the LGN3 database was limited. For the areas where LGN3 was classified with satellite data from 1995, we choose TOP10-vector tiles with acquisition dates between 1994 and 1996. For the areas where LGN3 was classified with satellite data from 1997, we choose TOP10-vector tiles with acquisition dates between 1994 and 1998. In order to determine the "new" land use we used the 0.5-meter aerial photographs. Although these photographs were taken in May 2000, we used them as reference to the true land use for the entire LGN4 database.

III. RESULTS

A. Land use changes in the Netherlands

Table 1 shows the land use changes in the Netherlands over the period 1995-2000 as derived from the LGN4

database. Over this period nearly 1% of the Dutch territory has changed function. Urban expansions and new nature areas in particular have increased strongly. In addition, the relatively large expansion of greenhouses (7.67%) is remarkable. The table does not provide insight in the change relationships, but in general can be stated that the expansion of greenhouses, urban areas, water and nature have caused a decrease in the total area of agricultural land.

TABLE I.   LAND USE CHANGES IN THE NETHERLANDS AS DERIVED FROM THE LGN4 DATABASE.

LGN4 class	Total area [ha]	Changes [ha]	% of class area
Agriculture	2256640	4435	0.20%
Greenhouse	13483	1034	7.67%
Orchards	27901	1167	4.18%
Forest	311799	1016	0.33%
Water	777493	2297	0.30%
Urban area	489787	19919	4.07%
Infrastructure	100503	196	0.20%
Nature	175102	8813	5.03%
Total	4152708	38879	0.94%

B.   Accuracy of land use changes

The results of the validation were visualised through a simple 2x2-confusion matrix (Table 2). From this matrix it can be concluded that the user's accuracy for both the change and no-change classes is nearly "1". This is not surprising because the "no-change" class has only been sampled 74 times and the chance of sampling a "no-change" point which is changed according to the reference data is very small. Furthermore, the lgn4-changes that are in error have little effect on the user's accuracy because the map proportion of the "change" class is very small. Also the producer's accuracy of the "no change" class is "1" for the same reason that the number of sample points for this category is small.

The most interesting value that can be derived from the confusion matrix is the producer's accuracy of "change" class, which is 0.759. These results demonstrate that the LGN4 database has a reasonable producer's accuracy with regard to land use changes. However, from the confusion matrix it could be concluded that the LGN database systematically overestimates the total area of land use changes with around 25%.

TABLE II.   CONFUSION MATRIX FOR THE LGN4 LAND USE CHANGES

LGN database	Reference data		Total	Producer's accuracy
	No-change	Change		
No-change	0.9903	-	0.9903	1
Change	0.0023	0.0073	0.0096	0.759
Total	0.9926	0.0073		
User's accuracy	0.997	1		

The change/no-change confusion matrix can also be converted into a matrix that shows the accuracy of individual change classes. However, due to the large number of possible change classes (7*8=56) and the limited number of sample points, there are many classes with no or little sample points.

Table 3 shows the user's and producer's accuracy of selected change classes that had more than 10 sample points. The user's accuracy for these classes is again very high, while the producer's accuracy ranges from poor (0.36) to high (0.82).

TABLE III.   USER'S AND PRODUCER'S ACCURACY FOR SELECTED CHANGE CLASSES.

Change class	User's accuracy	Producer's accuracy
Agriculture -> orchards	1.00	0.36
Agriculture -> water	0.90	0.91
Agriculture -> urban	0.99	0.82
Agriculture -> nature	1.00	0.71
Orchards -> agriculture	1.00	0.56

IV.   CONCLUSIONS

With the LGN4 database we have demonstrated that a land use change database can be obtained using a relatively simple methodology. The validation of the land use changes was carried out using 394 random points. Based on this validation, the LGN4 change database has a producer's accuracy of 0.759 for the land use changes. However, the current methodologies for validating a change database are not perfect and further research is necessary for properly validating a land use change database.

REFERENCES

[1] R.K. Kaufman and K.C. Seto, "Change detection, accuracy, and bias in a sequential analysis of Landsat Imagery in the Pearl River Delta, China: econometric techniques," *Agriculture, Ecosystems and Environment,* Vol. 85, 2001, pp. 95-105.

[2] P.F. Fisher, "The ordering of multitemporal fuzzy land-cover information derived from landsat MSS data," *Geocarto International*, vol. 8(3), 1993, pp. 5-14.

[3] Singh, "Digital change detection techniques using remotely-sensed data," Int. J. Remote Sensing, Vol. 10, No. 6, pp. 989-1003.

[4] J.F. Mas, "Monitoring land-cover changes: a comparison of change detection techniques," *Int. J. Remote Sensing*, Vol. 20, No. 1, 1999, pp. 139-152.

[5] L. Bruzzone and D. Fernández Prieto, "A minimum-cost thresholding technique for unsupervised change detection," *Int. J. Remote Sensing*, Vol. 21, No. 18, 2000, pp. 3539-3544.

[6] L. Bruzzone and B. Serpico, "An interative technique for the detection of land-cover transitions in multitemporal remote-sensing images," *IEEE Trans. Geosci. Remote Sensing*, Vol. 35, No. 4, 1997, pp. 858-867.

[7] H.A.M. Thunnissen, M.N. Jaarsma and O.F. Schouwmans, Land cover inventory in the Netherlands using remote sensing; application in a soil and groundwater vulnerability assessment system. *Int. J. Remote Sensing*,Vol. 13, 1992. pp. 1693-1708.

[8] C.J. de Zeeuw, A.K. Bregt, M.P.W. Sonneveld and J.A.T. van den Brink: Geo- information for monitoring land use. In: *GIS 2000 conference proceedings*; March 13-16, 2000, Toronto. Boulder CO (USA), GEOTec Media, [2000].

[9] J. De Gruijter, "Spatial sampling schemes for remote sensing" In: *Spatial Statistics for Remote Sensing,* Stein et al., eds. Kluwer: Academic Publishers, The Netherlands, 1999, pp. 211-242.

[10] D.H. Card, "Using known map category marginal frequencies to improve estimates of thematic map accuracy," *Photogrammetric Engineering and Remote Sensing*, 1982, pp. 430-439.