Land cover change detection in northern Belarus

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Abstract. Study deals with the land cover dynamics analysis using remote sensing data over urban, suburban area in northern Belarus (Polotsk and Novopolotsk cities and surroundings) over the period 1994 – 2002. SPOT 3 and 5 images are used for the study. Land cover change detection is conducted using image differencing and post-classification comparison methods. Several classification methods are tested in order to obtain the best classification results to produce single date maps and change map.

1 Introduction

Land cover dynamics is one of the main interests of environmental monitoring. Land cover undergoes changes caused as natural so mankind factors. Nowadays, anthropogenic factors, e.g. urbanization, agricultural intensification, etc become more significant sources altering earth's surface, while natural factors also play important role. Up-to-date land cover information is required by a great number of users.

Monitoring of land cover and land use is one of the main applications of remote sensing based change detection. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times [2, 7]. Remote sensing based change detection applies comparison of a set of multitemporal images covering time period of interest using specific change detection algorithms. There are tens of change detection approaches. They can be classified according to different criteria. Change detection methods can be divided into post-classification (map-to-map) and spectral (image-to-image) methods [3, 5]; methods able to extract "change/no-change" and "from – to" change information; etc. Usage of one or another method depends on application task, changes to be detected, data available, accuracy required, etc.

Among the most common methods of change detection using remote sensing data is image differencing, principal component analysis, post-classification comparison, spectral mixture analysis, write function memory insertion, and integration GIS into analysis [2] as well as combination of different methods of change detection [1]. The main objective of the study is to estimate the areas of significant changes over Polotsk and Novopolotsk cities and surroundings, kind of changes during the period 1994 –

2002, to estimate the accuracy of change detection results. In current study image differencing and post-classification comparison are used to detect changes over a part of Belarus. Change detection results are evaluated using accuracy assessment statistics, error matrices.

2. Study site and data discription

Polotsk and Novopolotsk are cities located in the north of Belarus. Polotsk is the oldest city in Belarus. Novopolotsk is one of the youngest cities and the largest industrial centers in Belarus. They are located just several kilometers from each other. Polotsk and Novopolotsk extend fast. Around cities are mainly forest areas including forest sanitary protective zone [6], agricultural areas, grassland, etc Main characteristics of north-Belarusian landscapes are small sizes, high diversity and complexity of landscapes, large number of lakes, hollows [6].

Three SPOT images from the 24th of July, 1994 (multispectral 20m, panchromatic 10m) and the 19th of July, 2002 (multispectral 10m) are used in the study. They are obtained in the UTM-84 projection. Small areas of images were covered by clouds and were excluded from the studies.

Analysis is performed using PCI Geomatica 10 software.

3. Methods

Two change detection methods are used in current study: image differencing and post-classification comparison.

The first method belongs to "change / no-change" methods. It is performed by subtracting corresponding channels of 2002 image from the 1994 one.

Image differencing is used mainly in current study to detect areas of significant land cover changes e.g. conversion between land cover types. Method does not require atmospheric correction, but requires careful selection of "change / no-change" thresholds [1].

Post –classification comparison method is one of the most widely used methods of remote sensing change detection. Among the main advantages of the method are:

- no need in radiometric co-registration of images involved into the analysis [1];
- lower than of spectral change detection methods sensitivity to the spectral variations due to difference in the soil moisture, vegetation phenology [4];
- provision with "from-to" change information [1];
- quite high change detection accuracy [4].

Among the main disadvantages of the method is dependency on the accuracy of individual classification results and it is also quite time consuming.

The general sequence of the change detection analysis is presented in figure 1.

Land cover change detection scheme used in current study was chosen considering local condition, classes of interest, reference material available. Classification scheme includes the following classes: water, developed areas (low density residential, high

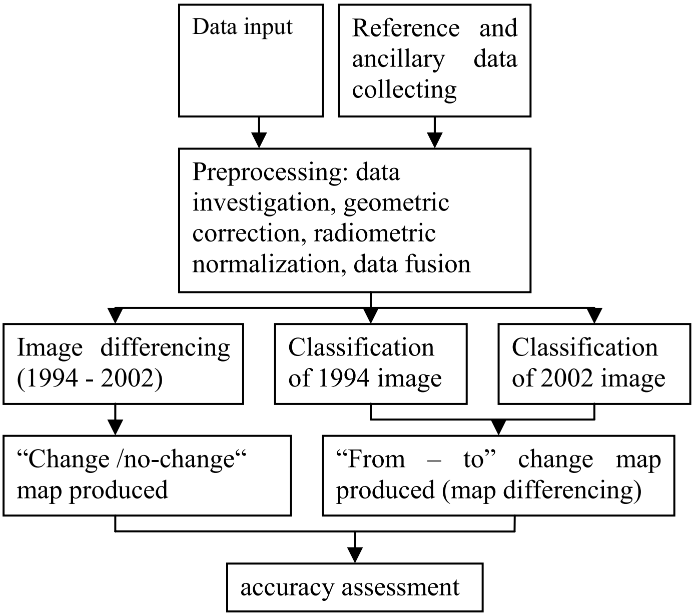

Figure 1. General sequence of land cover change detection.

density residential, commercial / industrial), transportation, open land, forest (deciduous, coniferous, mixed) and bushes, grassland, agricultural (arable, meadow, gardens), wetlands (forested, grassed). The change/no-change land cover detection is also conducted.

Accurate data preprocessing is crucial for reliable change detection results. Images obtained for current study were geometrically corrected but additional geometric co-registration of images is required in order to remove significant image displacement. Fusion of multispectral and panchromatic images from 1994 is performed in order to improve spatial resolution of 1994 XS. RGB – IHS transformation (using histogram normalization) is applied.

Image differencing was carried out for fusion outputs for 1994 image and corresponding 2002 image channels XS 1 (0.50 – 0.59), XS 2 (0.50 – 0.59), XS 3 (0.78 – 0.89).

When carrying out post-classification comparison several classification algorithms and approaches are tested in order to choose the ones showing highest classification accuracy and performance results. Among them are k-means, maximum likelihood classification, and artificial neural network. K-mean is unsupervised classification methods. Clusters produced by it are also used to collect training areas for supervised methods. Artificial neural network classification is conducted using back-propagation neural network classifier is used.

Single date error matrices, change/no-change error matrices as well as overall accuracy, producer's accuracy, user's accuracy and Kappa coefficient are used to assess the classification and change detection accuracy. 600 samples are collected using stratified random sampling method to assess classification and change detection ("change / no-change") accuracy.

4. Results and Discussion

Images were geometrically co-registered using 16 control points and applying polynomial 3rd order transformation, nearest neighbour resampling method. Root mean square error obtained is in the range 0,18 – 0,20 pixels. Image fusion is performed over 1994 images using RGB-IHS transformation. Radiometric normalization is performed using regression. Non-turbid water, concrete road, and dense forest are used as a pseudo-invariant features to derive normalization equations.

4.1 Image differencing

Three difference images were obtained. The difference results for channels XS 2 and XS 3 have similar difference values. Several thresholds were tested in order to obtain the reliable "change/no-change" results. Figure 2 presents the histogram for the difference channel XS 1. The pixel values undergone changes between two dates appear at the tails of the histogram.

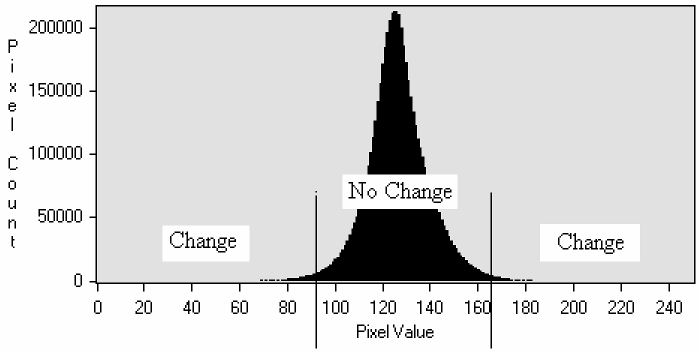

Figure 2. Histogram of XS 1 channels differencing. Vertical lines indicate threshold value.

Final change map obtained changes detected using difference results for channels XS 1 and XS 2.

An accuracy assessment statistics for change image produced using image differencing is presented in the table 1.

The accuracy assessment results present quite low user's accuracy for the class "change" caused by high commission errors. It means that only 64,3 % of the areas identified as change are actually change.

Table 1. Accuracy assessment of change map produced using image differencing method

Class	Producer's accuracy, %	User's accuracy, %	Kappa statistic
No change	86.3	94.8	0.77
Change	84.0	64.3	0.53
Overall accuracy: 85.8 %, Overall kappa statistic: 0.63%			

4.2 Post-classification comparison

Three classification methods are tested in current study. Overall accuracy is in the range of 75,0 – 86,3 % for 2002 and 1994 images. Maximum likelihood and neural network classification methods present higher accuracy assessment results (83,1-86,3%) and are used for change detection.

Change/no-change error matrix is produced for change detection maps. Overall accuracy of change maps is 71% and 69% respectively what is lower than using image differencing method.

Misclassification of the classes "agriculture", "open land", and "grassland" as well as "built-up" and "transportation", etc caused classification errors, which propagate and contribute to change detection error.

Six classification and three change detection maps were produced.

Among false changes are linear features next to the edges of the objects. The reason of that can be misregistration of the images in spite of quite high co-registration accuracy, inconsistency in spectral characteristics on the edge of objects. Agricultural area appeared to produce large amount of false changes when using image differencing method. It is caused by the difference mainly in crops and moisture. Both image differencing and post-classification comparison proves their ability to be used for detecting land cover changes over northern Belarusian landscapes. Presented study allows estimating the amount of changes occurred at the study area. But considering accuracy assessment results farther improvement of classification and change detection results is needed. Nevertheless significant land cover change are detected at the study area during the period 1994 – 2002. These changes are mainly roads and buildings construction, forest cutting, etc). But amount of errors and uncertainties requires additional study.

4.3 Further research issues

Among the main limitations and therefore issues to be considered for future study are: improving images co-registration by introducing larger number of control points as well as testing other math models; applying check points for co-registration accuracy assessment; testing other image fusion algorithms like wavelet analysis enabling better preserving of spectral information and still improving spatial resolution; testing other change detection methods; classification approaches, e.g. using texture analysis, introducing change error matrix to estimate "from – to" changes, etc.

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