Object-oriented classification of Landsat imagery and aerial photographs for land cover mapping

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Abstrakt. Príspevok sa zaoberá metódami a využitím objektovo-orientovanej klasifikácie obrazových údajov DPZ s vysokým a veľmi vysokým rozlíšením. Digitálne letecké a družicové snímky predstavujú zdroj presných a aktuálnych údajov pre mapovanie krajinnej pokrývky a monitorovanie zmien krajiny. Popri známej metóde vizuálnej interpretácie sa v súčasnosti presadzujú nové automatizované metódy obrazovej klasifikácie, medzi ktoré patrí aj objektovo-orientovaná klasifikácia. Táto metóda využíva homogénne obrazové objekty (segmenty), ktoré klasifikuje na základe spektrálnych, tvarových, textúrnych, kontextových a iných vlastností, čím sa snaží napodobniť proces prebiehajúci pri vizuálnej interpretácii. Na rozdiel od toho, klasifikácia založená na pixloch vytvára triedy len na základe spektrálnych vlastností individuálnych pixlov. Testovali sme viacero metód objektovo-orientovanej klasifikácie obrazových údajov so stredným rozlíšením (Landsat) a s veľmi vysokým rozlíšením (digitálna ortofotosnímka) v prostredí eCognition. Výsledky sme porovnávali s výsledkami klasifikačných metód založených na pixloch. V oboch prípadoch došlo k zvýšeniu presnosti. Ďalšou testovanou metódou bola poloautomatizovaná klasifikácia, ktorá spočívala v manuálnej reklasifikáciu areálov vybraných tried. Správnosť sa takisto oproti plne automatizovanej klasifikácii zvýšila. Súčasťou experimentu bolo aj vylepšenie výsledných vrstiev krajinnej pokrývky za účelom zvýšenia interpretovateľnosti. Proces zahŕňal odstránenie malých areálov a vyhladenia hraníc. Po takýchto úpravách je vizuálna kvalita vrstiev porovnateľná s kvalitou vrstiev krajinnej pokrývky interpretovaných človekom. V závere príspevku hodnotíme využiteľnosť údajov o krajinnej pokrývke získaných rôznymi metódami interpretácie pre aplikácie v prostredí GIS.

Klíčová slova: objektovo-orientovaná klasifikácia, letecké a družicové snímky, krajinná pokrývka.

1 Introduction

Land cover mapping represents probably the oldest and the most spread utilization of remote sensing images. In present, digital land cover data in raster or vector format belong to most important inputs into geographical information systems (GIS). Especially in support of environmental assessment, the need for updated information on land cover has become important both at the European and national levels [3].

Digital aerial and satellite images represent actual and accurate data source for land cover mapping and landscape change monitoring. The most detailed way of mapping land cover is with field data. But using field data, it is often difficult to assess regional patterns and access remote areas, and this data collection is costly and time-consuming, making it almost impossible to map large areas. Commonly used data (?) for land cover mapping are the aerial photographs, which allow for medium sized areas to be mapped at a level of detail appropriate for land cover mapping. Land cover mapping is usually done using aerial photographs with a resolution between 1: 10 000 and 1: 40 000 [12]. In past decade, satellite imagery is increasingly being used for large area land cover mapping. Satellites produce multispectral, panchromatic, thermal, and radar imagery. Satellite imagery also ranges in spatial and temporal resolution. Satellites with coarse and medium spatial resolutions are useful for large area land cover mapping, as a single image covers a relatively large area. Other benefits of using satellite imagery for land cover mapping include the visibility of regional patterns and the availability of temporal data sets [12].

Aerial photographs (today in digital format) and satellite images with high resolutions (pixel size less than 10m) are usually processed into the form of digital orthophotoimages with no distortions caused by elevation. This is a non-trivial process which requires special photogrammetric software, set of accurately measured control points and check points and digital surface model [5, 7]. The most often used method for land cover mapping using digital orthophotoimages (and remote sensing data in general) is visual interpretation. Among this old and well-known method, automatic (user-assisted) methods of supervised and unsupervised classification were also developed, but most of them is effective for coarse and medium resolution image data only. With the advent of high-resolution satellite imagery, the heterogeneity of land cover classes became greater. Consequently, the classification by traditional, pixel-based method is more difficult and results in the well-known salt-and-pepper effect. This is because these methods are based solely on the analysis of the spectral characteristics of individual pixels.

For the high-resolution remote sensing products, the methods of object-based (object-oriented) classification are more appropriate. In contrast with per-pixel classification methods, object-oriented classifiers use both spectral and spatial patterns for image classification. This is a two step process involving (a) segmentation of the imagery into discrete objects, followed by (b) classification of those objects. The basic assumption is that the image being classified is made up of relatively homogeneous patches larger in size than individual pixels [6]. This approach is similar to human visual interpretation of digital images and results in more compact classified image.

The aim of this article is to bring a short characteristic of this relatively new classification method and show the results of its usage for high (Landsat) and very high resolution imagery (digital orthophotoimage).

2 Principles of object-oriented classification

The first and key step in object-oriented classification is the process of dividing image into homogeneous regions called image objects or segments. Because the image segmentation is widely used method not only in the field of remote sensing, many different segmentation algorithms have been developed. We could divide them into several main groups - thresholding, region growing, splitting and merging, texture segmentation and watershed segmentation algorithms.

Most of these algorithms allow creating segments of different scale using some threshold parameter (Fig. 1.). The scale of the objects is one of the key variables influencing the image segmentation step [6]. The problem is that a large number of ways exist in which a study area can be divided into non-overlapping areal units for the purpose of spatial analysis [1], and this is the same in the image. Therefore no solution is universal and meaningful for all types of analysis.

Fig. 1. Multiresolution segmentation with scale parameter 25 (left) and 50 (right)

Once an image had been segmented, there are many characteristics that can be used to describe (and classify) the objects. Basic region-based classification algorithms use only the properties that are intristic to each object like spectral properties, texture, shape, etc. In contrast, object-oriented classifiers are based on object-oriented approach, so the image objects are mutually connected and “know” each other, what allows including the context information into the classification. If segmentation algorithm produces image objects in more than one hierarchical level, this approach is capable to preserving also the “parent-child” relationships among objects. For this purpose, the multiresolution segmentation algorithm was implemented in software eCognition Developer from Definiens AG, which we could consider as a commercial leader in the field of object-oriented image analysis. Other software for object-oriented classification is Feature Analyst (Visual Learning Systems, Inc.) distributed like an extension for ArcGIS and ERDAS IMAGINE. Finally, the new version of Idrisi Taiga (Clark Labs) allows the image segmentation and region-based classification too.

3 Object-oriented classification of Landsat imagery

We performed object-oriented classification in eCognition using two different types of remote sensing data – high resolution satellite imagery and very high resolution digital orthophotoimage. In first case, we classified a part from Landsat scene located in the north of Slovakia containing Low Tatras, Liptov basin and Liptovska Mara dam (Fig. 2.).

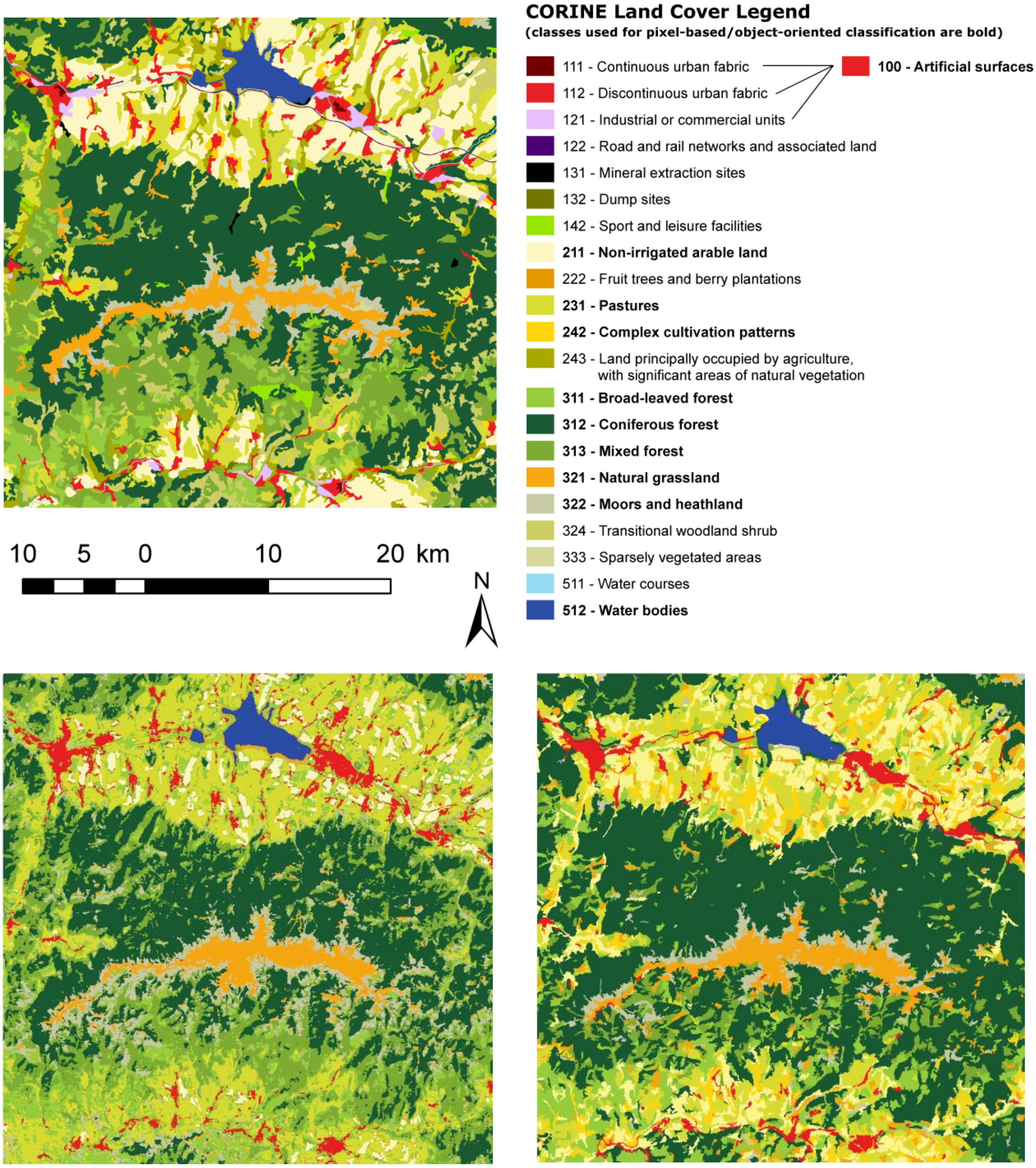

Fig. 2. Land cover maps of northern Slovakia created by visual interpretation (upper left), pixel-based classification (bottom left) and object-based classification (bottom right)

As a classification scheme we chose CORINE Land Cover (CLC) Legend due to its specification for this kind of data. But CLC classes are designed for visual interpretation method, so not all of them could be recognized without special human knowledge about land use or adding information from maps. Therefore we had to reduce the legend for automatic classification from 21 land cover classes occurring in the study area to 10 final classes [11]. This was done after a lot of testing via initial classification using different object features as well as class-related features in eCognition (class related features are object dependent features which refer to the class of other image objects situated at any location in the image object hierarchy [2]).

eCognition offers two main classification methods – fuzzy classification by user-defined membership functions (MF) and fuzzy nearest neighbor classifier (NN). The second one is easier due to automatic generation of fuzzy membership functions from user-selected sample image objects. NN classifier then operates in feature space, which is defined manually by user-selected features or automatically via feature space optimization.

For comparison, we classified the same image also via pixel-based approach in Idrisi Kilimanjaro using unsupervised ISODATA classifier and supervised maximum likelihood classifier. Fig. 2. shows the results of object-oriented classification in contrast with those of maximum likelihood classifier. Land cover layer created by object-oriented classifier is much better for perception and expert interpretation, because it contains more compact areas and no salt-and-pepper effect. Concerning classification accuracy, object-oriented approach provides also the better results (Tab. 1.).

Table 1. Accuracy of Landsat imagery classification

Classification method	Overall accuracy	Kappa statistics
Pixel-based ISODATA classifier	61,3 %	0,56
Pixel-based maximum likelihood classifier	76,9 %	0,73
Object-based fuzzy nearest neighbor classifier	84,0 %	0,80

4 Object-oriented classification of digital orthophotoimage

As we mentioned above, region-based classification methods are preferable especially for high and very high resolution data. The special case represents aerial photographs which for the automatic interpretation by traditional multispectral classifiers is not suitable. For example in B&W photographs, many different areas are formed by pixels with the same values and on the other side one class is formed by wide range digital values. The spectral signature space for individual classes overlapped and could not have been used for their distinguishing in this state [4].

Therefore we replaced pixel-based classification by object-based method. As an input data for testing we used the digital orthophotomosaic created from 24 color aerial photographs at the scale approximately 1: 27 000. These photographs were processed as a one block via digital automatic aerotriangulation, followed by digital orthophotoimages production and mosaicing. Whenever we plan to use digital orthophotomosaic for automatic classification, it is necessary to eliminate radiometric differences between individual images. Such radiometric unhomogeneity results in big classification errors and sometimes fully disables the automatic classification process. For radiometric balancing we used the dodging algorithm, which corrects the tonal imbalances across a tiled image. Output orthophotomosaic with resolution of 1m covered central part of Low Tatras [10].

We classified two sections of this mosaic – section A with size 2km x 3,2km, located in the ski resort Chopok-Jasná, and section B with size 2km x 2km near the upper forest level. As a classification scheme we used the legend proposed special for land cover mapping in Slovak high mountain areas on the base of digital othophotomaps [8]. This legend stems from the CORINE Land Cover legend and extends it by adding new level, details of which match the cartographic outcomes in scales 1: 10 000 to 1: 5000.

In eCognition we tested tree classification methods - fuzzy nearest neighbor classifier (NN), classification using membership functions (MF) and combination the both methods. The class hierarchy was built-up consisting from parent classes as well as the child classes. Class hierarchy in eCognition is established on the inheritance, where child classes inherit description of their parent classes. In section A class hierarchy, parent classes were based on the spectral characteristics and classified using NN classifier, in contrast with child classes defined by shape, texture or class-related features via membership functions. As expected, the combine classification method provided better results due to delineation of child classes (Tab. 2.).

In case of section B, the class hierarchy was more complicated. It consisted of 5 hierarchical levels, some of them based on height according to the great effect of this feature on the vegetation distribution in high mountain areas. For including height into the classification, we used digital elevation model of the area. Other levels or classes in the class hierarchy depended especially on spectral characteristics. Whole class hierarchy was built-up using combination of membership functions.

However, a lot of target classes in section A and B still left unclassified, e.g. artificial or heterogeneous areas. Some of these classes could be delineated via manual reclassification of existing image objects. eCognition provides a lot of tools for manual editing of classification results, so it's not necessary to use additional GIS software to do it. This semi-automatic approach is quite popular, especially in operation programs, which require very accurate results. In our project, land cover layer created by semi-automatic classification had also significantly higher accuracy than corresponding result of fully automatic classification (Tab. 2.).

Table 2. Accuracy of digital orthophotoimage classification

Classification method	Overall accuracy	Kappa statistics
Section A		
Automatic fuzzy nearest neighbor classifier	75,0 %	0,57
Automatic combine classification	78,2 %	0,62
Semi-automatic combine classification	92,5 %	0,88
Section B		
Automatic classification using membership functions (MF)	78,8 %	0,72
Semi-automatic classification using MF	91,8 %	0,89

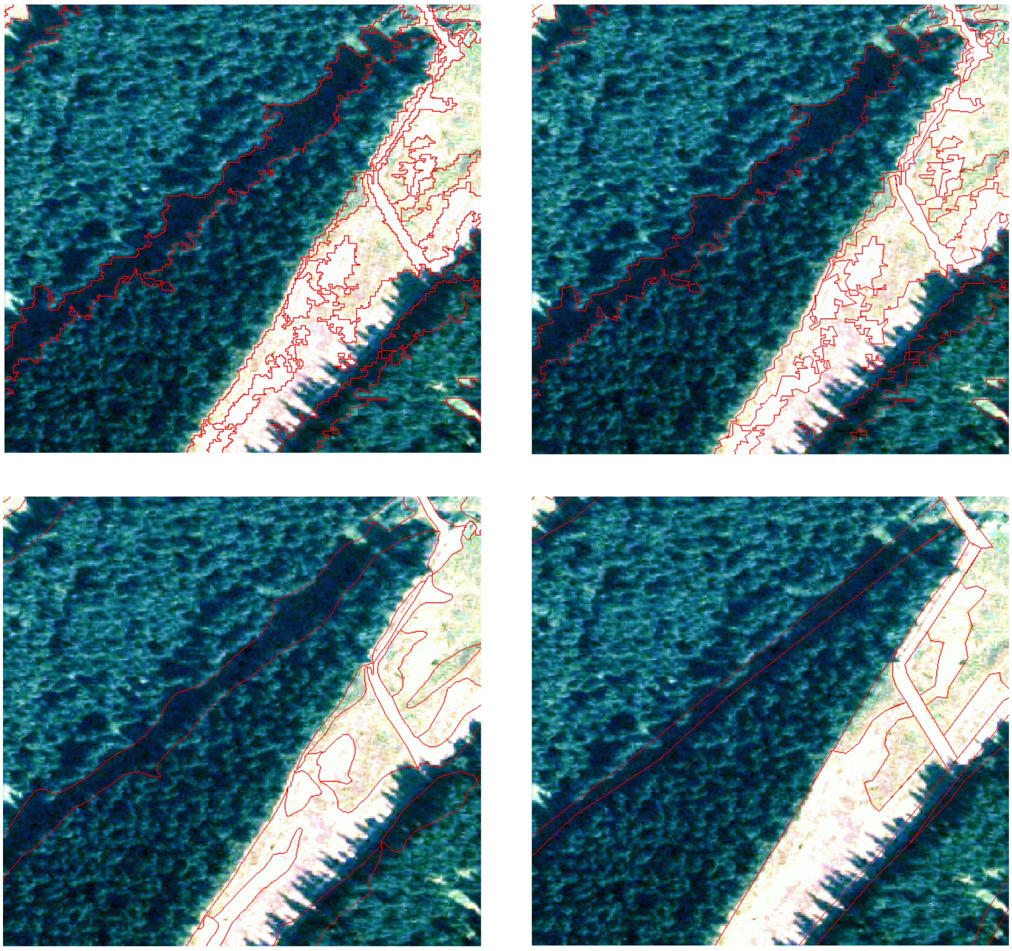

Fig. 3. Object boundaries – original (upper left), smoothed in eCognition 3.0 (upper right), smoothed in ArcGIS by PAEK algorithm (bottom left), created by visual interpretation (bottom right)

In spite of that object-oriented classification eliminates the salt-and-pepper effect, some of resulted areas are still too small or have a complicated shape. Small areas we can exclude in eCognition using object feature Area (after merging operation applied on adjacent objects of similar class). During export process, eCognition also allows the boundaries smoothing, but this generalization is not sufficient (Fig. 3.). Therefore we enhanced the original polygons in ArcGIS environment via Smooth line function with PAEK algorithm. But few weeks ago (in November 2009) Definiens brought a new version of eCognition Developer 8.0, which offers the new processes of pixel-based object generalization including growing, shrinking and coating objects with different parameters (e.g. the surface tension affecting the degree of smoothing).

Using tools for classification results enhancement, we can obtain land cover layers with similar interpretation quality as those created by human interpreter (Fig. 3.). You can ascertain this also on Fig. 4. showing the land cover maps of section B created by visual interpretation and object-oriented classification. It's apparent that the automatic segmentation and classification allows to distinguish landscape structure patterns (especially above the upper forest level) in more detail way.

Results of this project including visual interpretation, automatic and semi-automatic object-oriented classification as well as some change detection methods are published also on the internet. The web map application created using open source tools ka-Explorer! and MapServer is accessible via URL http://gis.fns.uniba.sk/hanele/chopok.

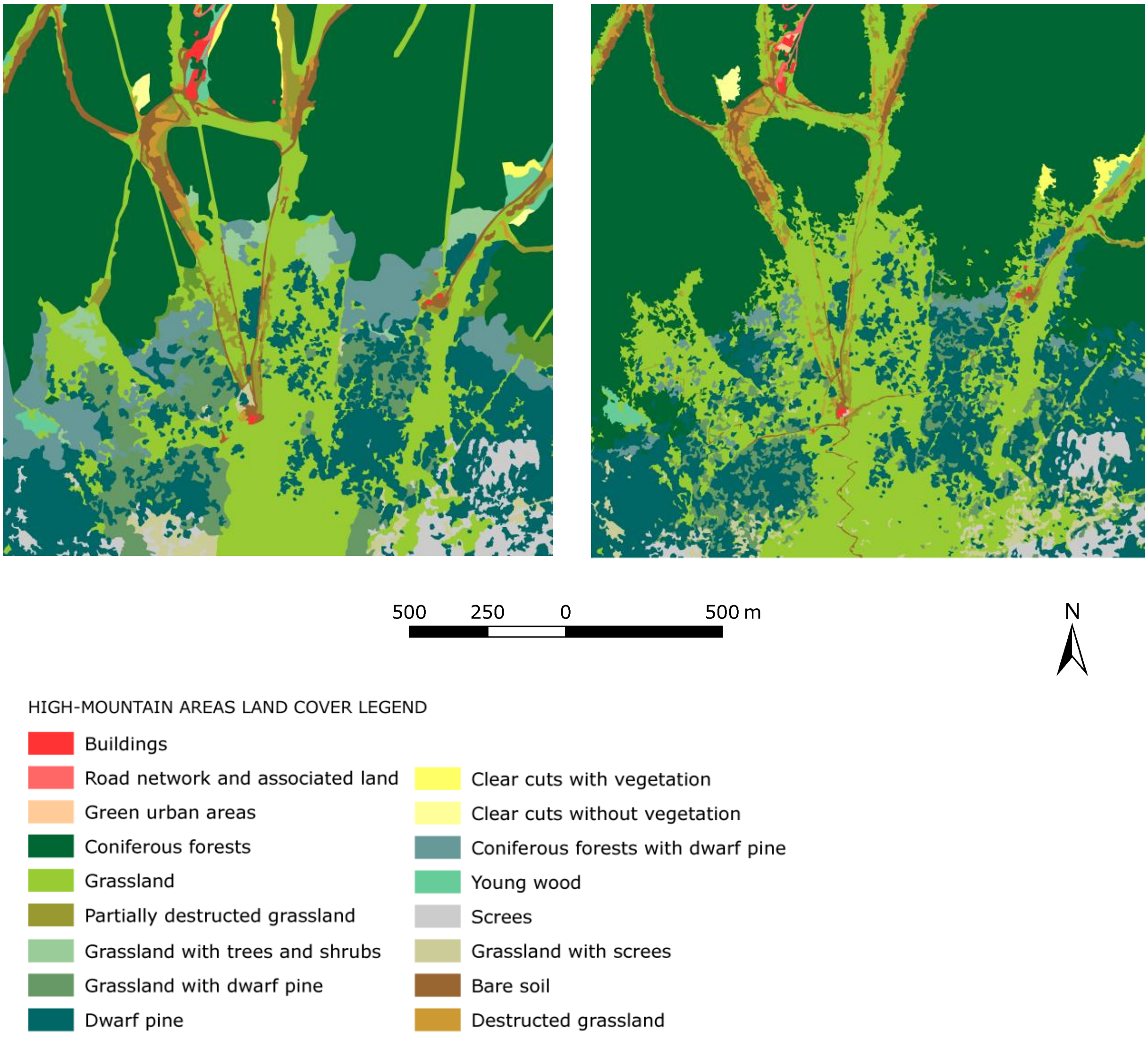

Fig. 4. Land cover maps of Chopok-Jasná (section B) created by visual interpretation (left) and semi-automatic object oriented classification (right)

5 Conclusions

Digital aerial or satellite images represent an accurate and actual data source about the state of the landscape in a certain time. Therefore the land cover mapping and monitoring as well as the landscape change detection based on remote sensing data are nowadays widely used. In order to higher efficiency, several methods of automatic image interpretation are still developing intensively. Besides the artificial neural networks, decision trees, context and knowledge-based or texture classifiers, object-oriented classification also belongs to this group.

Object-oriented classifiers are based on homogeneous image regions and mutual relationships between them. This approach brings the new possibilities into the classification and allows obtaining the results of high visual quality. Comparing with visual interpretation, object-oriented classification represents the strong tool, especially for land cover mapping in natural landscapes where the detail landscape structure has to be delineated.

After solving our research projects (and also due to other projects described in scientific literature), we must mention that object-oriented approach is not yet on the level of visual interpretation in recognizing objects. But the semi-automatic approach is very effective in many applications.

Actually, selection of the suitable interpretation method for land cover mapping using remote sensing data depends on the main target of the application. When we need the very precise results, e.g. by mapping of vegetation or other natural phenomena, we can apply the pixel-based classification on multispectral satellite data. Artificial surfaces can be interpreted in most effective way on the basis of aerial photographs or high resolution satellite images using the visual interpretation. For mapping of complex landscape structure at various scales, object-oriented classification with multiresolution segmentation is the most suitable method.

Special case represents the change detection process based on overlay of two or more land cover layers. In order to eliminate of sliver polygons, we must create the first (younger or older) land cover layer and then create the second land cover layer by modifying of the first layer only in the areas of change. Sliver polygons appear in the output of overlay operation when we compare the layers created independently. More polygons and more complex boundaries in the input layers result in more sliver polygons in the output. When we create the land cover layer as an input for some landscape model in GIS, i.e. in order to next spatial analysis, we should rather choose the visual interpretation or object-based classification for this purpose. These methods provide the more compact land cover areas, especially in combination with subsequent boundaries smoothing. The usage of object-oriented classification in the change detection process will be the subject of our next scientific research.

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