Applying fused multispectral and panchromatic data of Landsat ETM+ to object oriented classification

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ABSTRACT: The article presents results of object oriented classification of Landsat ETM+ satellite image using fused multispectral and panchromatic data. Channels 2, 3 and 4 of the ETM+ image have been fused by applying PanSharp automatic algorithm (PCI Geomatica software) which preserves spectral characteristics of multispectral channels. Object oriented classification has been performed using eCognition software. On the basis of original and fused data, the rules of segmentation have been specified. Next, identification of land use and land cover classes has been tested. Mean values, standard deviations, ratio parameters of the objects, as well as Haralick texture functions have been analysed. Using membership functions and Standard Nearest Neighbor classification, 18 land use classes has been defined and classified. Panchromatic channel has been used for the purposes of recognition of built-up areas, as well as for extraction of the mixed forest class from broad-leaved and coniferous forest. Performed work has demonstrated that fused multispectral and panchromatic data do not have significant influence on the improvement of land use classes separation during classification process, but they are useful for satellite image segmentation process.

1 SATELLITE DATA

Assessment of usefulness of fused multispectral (MS) and panchromatic (PAN) data in object oriented classification has been based on a Landsat ETM+ satellite image collected on 7 May 2000. Spring is not an optimum period of registering a image for the purposes of land cover classes' identification. Better results can be obtained, when identification is based on images made in August and September. However, due to limited availability of cloudless images, spring images are frequently used for identification of land cover classes.

Pre-processing of the Landsat ETM+ image involved the preparation of satellite data for object oriented classification. To this end, atmospheric correction and data fusion of multispectral data with the panchromatic channel were performed.

Atmospheric correction was performed using ATCOR2 software (Richter 2006), a module of the PCI Geomatica image processing system. A standard definition of the atmospheric conditions for the spring season and agriculture-dominated areas was applied.

Multispectral data of the Landsat ETM+ image were fused with the panchromatic channel using the PanSharp algorithm by Dr Y. Zhang (Zhang 1999, 2002), a module of the PCI Geomatica software.

The choice of this particular algorithm was not random. Majority of methods of fusing MS and PAN data based on IHS, PCA, HP method or Wavelet transformation have a major drawback: the achieved results depend on the skill of the operating person. It is particularly visible in the IHS method, used for the purposes of creating satellite maps (Lewiński 2000; Lewiński & Zagajewski 2002), as well as colour composites for visual interpretation (Lewiński & Poławski 2005). The PanSharp algorithm is a dedicated tool for fusing diverse satellite images of various spatial, spectral and radiometric resolution. It also offers an feature of automatic resampling, i.e. adjusting the size of pixels in the multispectral image to the panchromatic one.

Using the PanSharp algorithm, data fusion of satellite data after the atmospheric correction was performed. Three multispectral channels No. 2, 3 and 4, which from the spectral perspective matched the range of the panchromatic channel, were selected for fusing. As a result, three new channels were obtained: PANSHARP2, PANSHARP3 and PANSHARP4.

2 STUDY AREA

The study was performed on a subset of Landsat ETM+ image showing the area of 423 km^2, situated in central Poland, in the region of Masovian Lowland (Nizina Mazowiecka) near Warsaw. In the centre of the area, between the rivers of Vistula and Narew, there is the city of Legionowo (49,000 citizens). The area has coniferous and broad-leaved forests, arable lands, grasslands and built-up areas, mainly of discontinuous development. Rural areas are mainly scattered: the fields of arable land are small, often below 1 ha, adjoining the green areas. There is an artificial reservoir Zalew Zegrzyński on the river of Narew of the area of over 30 km^2.

3 SEGMENTATION

Segmentation of the Landsat ETM+ image was preceded by an analysis of statistical parameters of particular channels and the analysis of correlation coefficients. The parameters of segmentation, the number of created objects and their average area expressed in hectares are presented in Table 1.

Selection of the parameters of segmentation was connected with classification assumption - identification of objects of minimum area of 4 ha for all classes and 1 ha for water and built-up areas.

The first level of segmentation was performed exclusively on the basis of the panchromatic channel, using a low scale parameter and high values of *color* and *compactness* coefficients. Image of the study area was divided into 84183 objects of consistent shapes. The second segmentation is characterised by much higher scale parameter of the value of 23 and lower *color* and *compactness* parameters of equal value of 0.8. For the PANSHARP3 channel, weight 2 was applied, which – in this set of data – performed an averaging role for the PANSHARP4 channel, which has high level of standard deviation. 4269 objects were identified in the second level. The applied parameters enabled correct separation of the objects to be classified afterwards, including the objects of linear character.

Application of PANSHARP2, PANSHARP3 and PANSHARP4 channels in segmentation seems entirely justified. They contain a sum of information connected with multispectral channels and the panchromatic channel. The performed trials indicated that fused data increase the precision of identification of objects, as compared to multispectral data.

Table 1. The parameters of segmentation of Landsat ETM+ image – eCognition software.

level	parameter			channel				objects	
	scale	color	com-pactness	PAN	PAN-SHARP 2	PAN-SHARP 3	PAN-SHARP 4	number	aver. area (ha)
1	5	0.9	1	1	-	-	-	84183	0.50
2	23	0.8	0.8	-	1	2	1	4269	9.93

4 CLASSIFICATION

Classification of the Landsat ETM+ was performed on the basis of the second segmentation level (table 1). For the purposes of identification of land cover classes, the following functions of eCognition software were applied: Standard Nearest Neighbor (STD.N.N.) and parametric criteria.
Selection of the classification parameters applied in the nearest neighbour method was preceded by an analysis of discrimination of land cover classes. The following parameters of objects were analysed: average values, standard deviations, ration and Haralic functions connected with the texture of the image. The total of 14 parameters connected with the panchromatic channel, multispectral channels and PANSHARP channels were tested. For the purposes of specifying the discrimination parameters, the "Feature Space Optimization" function of the eCognition software was used.
The performed analyses proved that the panchromatic channel and PANSHARP channels do not have significant influence on discrimination of the defined land cover classes. However, it must be stated that relatively the best results were obtained for the PANSHARP4 channel, which has the highest level of standard deviation. Eventually, six parameters were chosen for application to STD.N.N. classification: average spectral values of channels 4, 5 and 7, ratio function applied to channels 3 and 7, GLCM entropy of channel 2.

The process of classification involved also parametric criteria existing independently or together with STD.N.N.. To this end, the criteria of object size, distance, shape, border and border length, belonging to another class and average and standard deviations connected with the selected channels were applied. Moreover, a dedicated criterion named ZABUD1 was used. The parameters mostly "cooperated" with the STD.N.N. method, although in the case of a few classes, they also functioned as independent classifiers.

18 land cover classes were classified. The principles of classification of particular classes and their codes based on the legend level 3 of the CORINE project (Heymann et al. 1993) are presented below. In respect of spectral similarity, some classes cannot be identified using traditional classification methods, which rely exclusively on the analysis of spectral values of satellite image pixels.

4.1 *Principles of classification of land cover classes.*

Built-up areas (1121, 1122, 1123, 121): four classes of built-up area were isolated from the major class of "built-up area", defined on the basis of STD.N.N and additionally limited by the criteria of the length of borders with water and by minimum width of the object.
Industrial areas (121) were isolated from the major class of "built-up area", applying the *ZABUD1* criteria and assuming that such areas do not adjoin built-up areas with apartment blocks and the object shape is near to rectangular. The *ZABUD1* criterion was also applied to identification of rural discontinuous built-up areas with family houses (1123) and discontinuous built-up areas (1122). Discontinuous built-up areas with apartment blocks (1121) was isolated from discontinuous built-up areas using classification on the first segmentation level, on the basis of which shadows of apartment blocks visible in the panchromatic channel were classified.
The *ZABUD1* criterion is not a standard feature of the eCognition software; it is a custom function, whose definition the eCognition software enables (Baatz and all, 2001). The criterion was applied to isolation of three subclasses from one major class: rural discontinuous built-up areas, discontinuous built-up areas and industrial areas. The applied formula is the following:

$ZABUD1 = ((ms2-ms3)^2 + (ms3-ms4)^2 + (ms4-ms5)^2 + (ms5-ms7)^2 + (ms7-pan)^2)^{0.5}$

where:

ms2, ms3, ms4,ms5,ms7 – average object values in particular MS channels

pan – average object value in the PAN channel

The biggest differences between the classes of built-up area are observed in the 4th and 5th spectral channels, which is connected with green areas within the analysed objects. The attempts to discriminate on the basis the 4th and 5th spectral channel value and the NDVI index, widely used in remote sensing, have not been successful, while the ZABUD1 criterion, taking into account the differences between particular channels, enabled discrimination between three classes of built-up area. Theoretically, the minimum value of the criterion is 0, when there are no differences in the spectral reflection between the channels. The ZABUD1 parameter can also be useful for identification of other land cover classes.

Liquid waste dumps (1322): STD.N.N classification and conditions of not bordering with water and connected with the width of an object.

Construction sites and beaches (133, 3311): In the Landsat image, both classes are very similar from the spectral perspective and, therefore, they were initially classified into one class according to STD.N.N., and then divided according to the criteria of distance from built-up areas and bordering with water. Construction sites and beaches were also isolated from the subclass of arable land without vegetation according to the criteria of area (small objects) and bordering with water and built-up areas.

Green urban areas (141): Green urban areas were isolated from two classes: “Agriculture areas with natural vegetation” and “Mixed forest”, according to the criteria of a long border with built-up areas (over 75%) and a defined distance from the city centre of Legionowo (the only larger city in the study area, where this class can be found).

Arable land – large blocks (21111): This class was classified with division into two subclasses: fields with no vegetation (bare soil) and fields with vegetation (winter crops). The first class was identified on the basis of STD.N.N.. To define the second class, for its spectral similarity to other areas covered with vegetation, STD.N.N. and the criterion of belonging to the class of “Agriculture areas with natural vegetation” were applied.

Arable land – small blocks (21112) (mosaic fields): STD.N.N. classification.

Greenhouses (2113): STD.N.N. classification and the criterion of rectangular shape.

Grasslands (231): STD.N.N. classification

Agriculture areas with natural vegetation (243): STD.N.N. classification

Broad-leaved forest (311): This class was classified according to STD.N.N. and the criterion of uniformity connected with the value and standard deviation in the panchromatic channel.

Coniferous forest (312): his class was classified according to STD.N.N. and the criterion of uniformity connected with the value and standard deviation in the panchromatic channel.

Mixed forest (313): This class was isolated from the classes of “Broad-leaved forest” and “Coniferous forest”. It was assumed that mixed forest is a coniferous or broad-leaved forest area which does not meet the uniformity criteria. The uniformity criteria was measured according to the average values in the panchromatic channel, in which coniferous forests have lower values of spectral reflection, as compared to broad-leaved forests. Mixed forest isolated from the coniferous forest has high values in the panchromatic channel – "light" coniferous forest. In the case of isolation from the class of broad-leaved forest, mixed forest has low values in the panchromatic channel – "dark" broad-leaved forest. Similar approach to the classification of mixed forest was taken in the classification of ASTER image (Lewiński 2006).

Transitional woodland (324): STD.N.N classification and the criterion of bordering with forests.

Water courses and bodies (51): This class consists of 3 subclasses: large rivers, small and shallow reservoirs and canals. Exclusively the parametric criterion of classification was applied, connected with the 4^{th} and 6^{th} spectral channel values (thermal) and the ratio between the length and width of objects (canals).

5 RESULTS

The classification image obtained as a result of the object oriented classification was generalised and tested using a method of visual interpretation. The same procedures as in the case of classification ASTER images (Lewiński 2006) were applied. It is presented in figure 1.

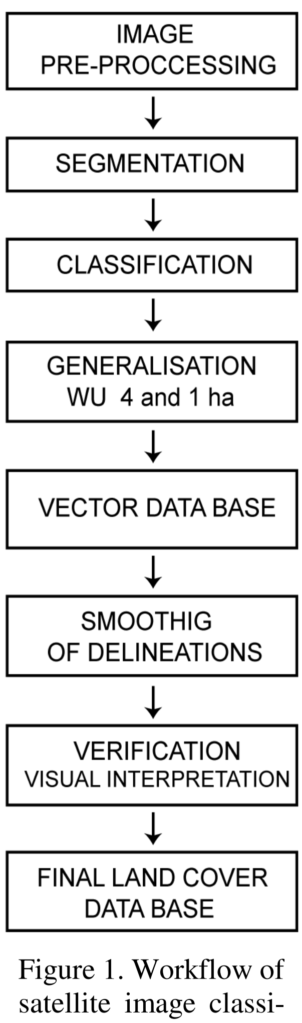

Figure 1. Workflow of satellite image classification

Generalisation was based on the classification data in raster format in the PCI Geomatica software environment. For classes connected with built-up area and water, WU=1ha (Working Unit) was adopted, while for other classes, Working Unit was 4 ha. Objects of the area below WU were included to larger neighbouring objects.

Next, raster to vector conversion was performed. The edges of objects along the edges of satellite image pixels were smoothed (using the feature of PCI Geomatica) in order to make them similar to the borders of visual interpretation are obtained.

Assessment of classification was performed using a method of visual interpretation according to the way adopted by CORINE 2000 project (Nunes de Lima 2005). The interpreter adjusted the edges of objects and the codes of classes directly on the screen displaying the vector database and the satellite image. As a result of interpretation, a so-called change layer was obtained, which provided information about the correctness of the classification.

Total accuracy of the classification reached 94.6%; there was also a high value of the statistical ratio K_{HAT}=93.9% (Congalton, 1991). From the perspective of the pruduser's accuracy, connected with omission errors, the least accurate was the classification of "Agriculture areas with natural vegetation" (243), "Rural discontinuous built-up areas with family houses" (1123) and "Grasslands" (231). The accuracy of identification of these classes was 78.7%, 87.4% and 93.9% respectively. Relative low user's accuracy (commission errors) is connected with the classes of "Broad-leaved forest" (311) - 81.4%, "Agriculture areas with natural vegetation" (243) - 89.8%, "Grasslands" (231) - 89.9% and "Arable land – small blocks" (21112) - 92.1%. Theoretically, the majority of mistakes may result from the fact that the classified image was taken in May. In the spring season, vegetation has a high level of chlorophyll, which causes a decreased spectral diversity between so-called green classes. It is also visible in the case of visual interpretation. On the other hand, mistakes in classification of rural discontinuous built-up

areas are mainly connected with scattered development; in the case of more dense urban built-up areas, the accuracy was much higher.
After consideration of change layer information the final land cover data base has been prepared.

6 CONCLUSIONS

This paper was aimed at assessing the usefulness of fused multispectral and panchromatic data of a Landsat ETM+ satellite image in object oriented classification of land cover forms.

Using the PanSharp algorithm, PAN data were connected with MS channels 3, 4 and 5. The performed analyses proved the usefulness of fused data, mainly at the stage of segmentation, which was performed on two levels. The first segmentation level was based on the PAN channel, while the second level was based exclusively on pansharp data.

In the classification process proper, i.e. in identification of objects, pansharp data did not have any significant role. However, from the three created channels, the PANSHARP4 channel had the greatest volume of information. The value of standard deviation for this channel is 30.62 and its the highest value, as compared to other data. Standard deviation for the two remaining channels - PANSHARP2 and PANSHARP3 – is much lower and amounts to 10.21 and 13.85 respectively. Similarly to the original data, PANSHARP2 and PANSHARP3 channels are well correlated with each other – the level of correlation is 0.97. At the same time, levels of their correlation with the PANSHARP4 channel are very low: 0.49, 0.37.

As it is suggested in papers on detailed object oriented classification of forests using HR images (de Kok et al. 2000a, 2000b), the panchromatic channel was used for the purposes of identification of forest's species. According to average values of objects in the PAN channel, mixed forest was isolated from coniferous and broad-leaved forest. The PAN channel was also used for identification of shadows of large buildings. PAN data were used as one of the parameters in the presented ZA-BUD1 criterion, applied to identification of classes of built-up area.

The applied method of processing the results of object oriented classification, involving generalisation, creation of a vector database with smoothing object edges and verification using a method of visual interpretation, can be used in a process of creating detailed land cover databases.

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