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ZASTOSOWANIE OBIEKTOWO ZORIENTOWANEJ ANALIZY OBRAZU (GEOBIA) WYSOKOROZDZIELCZYCH OBRAZÓW SATELITARNYCH W KLASYFIKACJI OBSZARU MIASTA KRAKOWA

USING THE OBJECT-BASED IMAGE ANALYSIS (GEOBIA) IN THE CLASSIFICATION OF THE VERY HIGH RESOLUTION SATELLITE IMAGES OF KRAKOW MUNICIPALITY

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SŁOWA KLUCZOWE: klasyfikacja obiektowa (GEOBIA), IKONOS, QuickBird, automatyzacja, pokrycie terenu

STRESZCZENIE: Technologie teledetekcyjne oraz systemy GIS osiągnęły obecnie poziom rozwoju umożliwiający pełną implementację automatycznych metod klasyfikacji oraz procesów kontroli i aktualizacji zasobów kartograficznych będących w posiadaniu administracji publicznej. Dane teledetekcyjne pozyskiwane nowoczesnymi metodami takimi jak: lotnicze kamery cyfrowe, skanery hiperspektralne, LiDAR bądź VHRS - pozwalają na poprawne skonstruowanie procesu wspomagania podejmowania decyzji na poziomie lokalnym i regionalnym takich jak np. miejscowe plany zagospodarowania przestrzennego. Ogromne zbiory danych (np. LiDAR, VHRS) muszą być coraz częściej poddawane automatycznym procesom ich przetwarzania. Obiektowo zorientowana analiza obrazu (*ang.* Object Based Image Analysis; akronim: GEOBIA) - zwana potocznie klasyfikacją obiektową, wykorzystuje zaawansowane algorytmy segmentacji rastra. Rozstrzygają one o liczbie generowanych obiektów na podstawie wartości jaskrawości piksela oraz „właściwości geometrycznych" (np. kształtu, grupowania się pikseli w homogeniczne obiekty, zwartości, etc). W kolejnych krokach obiekty te są klasyfikowane na podstawie licznych zależności i właściwości, jak np. parametru homogeniczności czy stosunku długości granic do powierzchni (wykrywanie krawędzi, budynków, działek etc). Klasyfikacja obiektowa może przyjąć strukturę hierarchiczną, to znaczy raz sklasyfikowane obiekty mogą posłużyć do stworzenia nowego wyższego hierarchicznie poziomu. Taka metodyka pozwala na przygotowanie scenariuszy postępowania klasyfikacyjnego zapisywanych do plików zwanych protokołami w oprogramowaniu DEFNIENS. Nowatorskie podejście do kwestii klasyfikacji obrazu bez potrzeby wykorzystywania pól treningowych zostało już potwierdzone wieloma projektami naukowymi i ich wdrożeniami (Wężyk, de Kok, 2005; de Kok, Wężyk, 2006).

W prezentowanej pracy do przeprowadzenia klasyfikacji wykorzystano 2 sceny IKONOS z dnia 25.06.2005 roku (łączny obszar 194,7 km^2) oraz 1 scenę QuickBird z dnia 07.09.2006 roku (167,7 km^2). Prace zostały zlecone przez Biuro Planowania Przestrzennego UM Krakowa w listopadzie 2006 roku. Obrazy VHRS poddano ortorektyfikacji (Aplication Master 5.0, Inpho) w oparciu o współczynniki RPC ale także punkty dostosowania GCP pozyskane z ortofotomap Phare 2001 oraz NMT przekazanego przez BPP UMK (Wężyk et al., 2006). Do analizy obrazów VHRS wykorzystano kanał panchromatyczny (PAN) oraz wielospektralne (MS) zakresy promieniowania. Wstępne przetwarzanie kanałów PAN polegało na zastosowaniu filtrów krawędziowych (np. Lee Sigma), w wyniku działania których otrzymano tzw. obrazy pochodne wykorzystane w procesie segmentacji. Inne obrazy biorące udział w tym złożonym procesie składającym się z 11 kroków to:

poszczególne kanały MS (Blue, Green, Red, NIR), dla których wykonano analizę głównych składowych (*ang.* Principal Component Analysis), mapa ewidencyjna (obraz rastrowy) wykorzystywana w projekcie kartowania zieleni rzeczywistej Krakowa (służąca głównie klasyfikacji budynków przy wykorzystaniu PC3), rastrowa warstwa sieci dróg pochodząca z wektoryzacji ekranowej VHRS i z map ewidencyjnych. W toku uzgodnień z BPP UMK podjęto decyzję o przyjęciu dwóch poziomów hierarchicznych klas pokrycia terenu. Poziom 1 składał się z 9-ciu klas zajmujących odpowiednio: tereny zainwestowane – 17,42%, zieleń wysoka – 24,99%, zieleń niska – 44,31%, zieleń terenów sportowych oraz ogródków działkowych – 1,39%, zbiorniki wodne i rzeki – 1,94%, infrastruktura drogowa – 3,48%, hałdy + wysypiska + odsłonięta gleba – 0,84%, grunty orne i uprawy – 5,35% oraz cień – 0,28% obszaru badań. Trzy klasy poziomu 1, tj.: tereny zainwestowane, zieleń niska i zieleń wysoka) zdecydowano się zaprezentować na wyższym – 2 poziomie szczegółowości. Wraz z pozostałymi klasami poziom ten składał się łącznie z 22 klas. Osiągnięte rezultaty potwierdziły szerokie możliwości stosowania automatycznych metod OBIA bazujących na VHRS i innych informacjach pochodzących z systemów GIS oraz z zasobów geodezyjno-kartograficznych w celu ich aktualizacji.

1. TRANSFERABILITY

In the remote sensing and GIS laboratories, much progress in image handling can be demonstrated. The various case studies produced with object oriented analysis (eCognition) in the Laboratory of GIS and Remote Sensing at the Agriculture University of Krakow has reached a level where the experimental results (de Kok et. al, 2005, 2006) can be put into commercial practice. For this, at the spin-off SME, the ProGea Consulting (www.progea.pl), the various academic studies are linked into a product chain for the commercial application purposes. During commercial processing, proven techniques must work under the stress of the deadline and production must be achieved using bulk data. Stability and transferability of automatic classification protocols is therefore a *sine qua non*.

A detailed mapping project with sub-meter resolution can be established using various area extensions or extensions of scale. Basically three levels of area extension are common; national, regional as well as local scale extension. Mapping a complete country (national scale or national extent) with IKONOS-2 or QuickBird-2 imagery is still an exception but regional and local mapping projects are standard practice. The paper describes the results of the eCognition ver.5 protocols for mapping area of 330 sq km of Krakow (Poland), using 3 VHRS scenes: two from IKONOS-2 (25.06.2005) and one from QuickBird-2 (07.09.2006). The original scale layout was defined by the cadastre maps (scale 1:5.000) with a resolution of 0,45m pixel size (scanned analogue maps; GeoTIFF format), organized in 42 map sheets covering the complete municipality. The three VHRS scenes were split into these 42 map sheets (frames) and georeferenced according to a local coordinate system (KUL).

The complete ongoing project, works with 2 main sources of geo-information, i.e.:

- the cadastral map,
- the VHRS imagery.

The combined sources of data allow for “data overkill” in the sense that certain features are registered three times without adding additional information into the GIS. For example the extraction of water surfaces only needs one of these sources to be completed if all information sources have an adequate up to date representation of the actual situation. Regarding time differences in the various data sources, a constant update using all three sources at the same time is impractical. Once cadastral and LiDAR campaigns are finished, a very regular update with VHRS analysis remains the attractive (low-cost) option. So the role during inventory and monitoring redefines very much the position of VHRS data in the process chain. The various strategies for updating and/or monitoring define the quality of the selected sensor types.

Data overkill in inventory (not in monitoring!) however is more and more becoming a daily practice, which changes the perspective of the remote sensing information extraction. In traditional remote sensing, all information inside the image was valuable and expensive enough to extract any detail inside the image even up to sub-pixel levels. Sub pixel levels in a QuickBird image become irrelevant on a local and regional scale especially in the face of high precision LiDAR data. The need for VHRS data in addition to LiDAR cloud point data is relevant in various ways although accepting a data overkill situation. The VHRS data serve very well in a correct stratification of the processing workflow and is very useful in pre-categorization of the basic domains: Water, Forest, Agriculture and Built-up areas. In LiDAR, agricultural fields (open soil) and various vegetation types are still too complicated to handle and can be served with a correct pre-stratification based upon VHRS analysis. The cost of VHRS data in a full campaign at local or regional scale however is rather small and therefore applicable. On the other hand data overkill enforces speeding up full automatic classification procedures because the decision rules will allow automatic cross checking of information through various data sources. This is definitely a benefit for full automatic sampling selection. Considering monitoring however, data overkill is radically reduced as VHRS data still allows the most recent details in the data for a rather economical coverage over the total local and/or regional extent of the area under observation.

2. FEATURE EXTRACTION FROM CADASTRAL MAPS

The three main themes during the extraction of cadastral information are: "Built-up areas", "Road systems" and "Water". Using the scanned paper maps as input, an object oriented approach allows for a standardized extraction of essential features. The extracted objects can than be confronted with new observations to register any type of change.

On the original paper print, the "Built-up area" is in most cases manually updated with a different dye than the original print. The characteristics of this deviating ink influences the results of the scanned paper map in GeoTIFF format. A principle component analysis of three bands GeoTIFF of this scanned paper map allows a separation of this deviating dye to be transferred to the 3rd Principal Component. This allows for a simple extraction of single buildings as objects in eCognition version 5 (Fig. 1). However these conditions are unique only for this set of cadastral paper maps and can not be expected in other projects. Applying this method on scanned topographical maps (1:5.000) of this area reveals the separation between dyes which fluorescent qualities responding quite different to principle component analysis than other dyes. This condition is valid for all topographic sheets from this period.

When using scanned maps in a production process and various sheets, it is of importance to check the properties of the original ink. It might be that different scanning conditions and wavelength of the lamp used during the scanning process might have considerably influence on the automatic feature extraction from scanned paper maps. A simple RGB scanner might deliver a product which allows for less feature extraction than optimized scanning conditions including the test on luminescence conditions of the dye on the original paper.

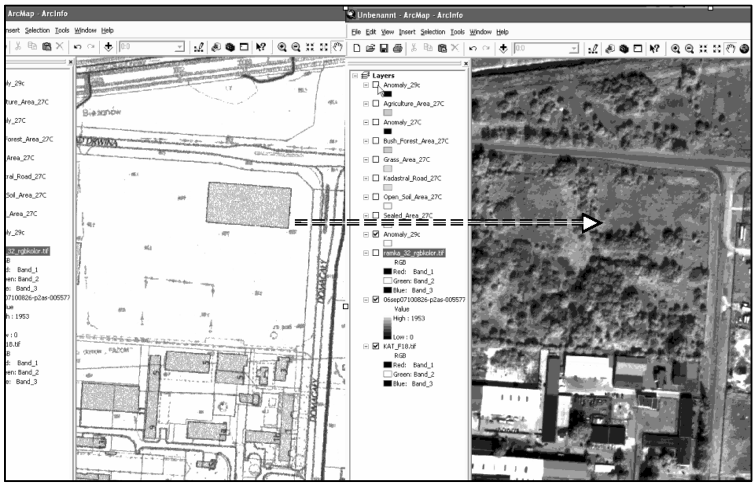

Fig. 1. Not only new buildings appear on the VHRS, also existing buildings in the cadastre map disappear. Often a situation which can be fully automatically detected using OBIA.

For treating line components on the scanned paper map, an additional Sobel filter (all directions) was applied. Even when, in a scanned map, the lines are all black, their neighborhood in the edge detection image might deviate, which expresses itself best in an additional line detection layer. Especially the height information is easier to separate after adding an edge detection filter in the analysis.

3. CUSTOMER DEMAND

The data collected from VHRS sources can be combined with other high quality data such as cadastral maps or most recent developments in LiDAR detection with 12 points per 1 sq m from helicopter (low altitude) platform. Therefore the speed and simplicity of satellite image processing has to be arranged in such a way that only necessary details are extracted. The customer defined 7 classes which is basically a separation of various vegetation surfaces from built-up terrain. Single building detection does not take place in the satellite image analysis but the sealed area classes are an input into the LiDAR analysis process in a further stage. The single building detection needs three details from the combined resources: Height (from LiDAR or very sophisticated multiple overlap derived from the digital scanner), Edges (from VHRS data or orthophotmosaic) and spectral properties (from Red and NIR VHRS data or CIR-orthophoto mosaic). The classes: cadastre and VHRS data lacks the LiDAR height for full automatic building detection. The developed classification is the intermediary input for this next processing step.

4. NDVI AND VEGETATION

Crucial in urban analysis is the split of vegetation versus non-vegetation with most of the time a central role of the NDVI. Due to the excellent properties of the panchromatic band in VHRS IKONOS and QuickBird, it is more useful to replace the NDVI with the Ratio of RED; (Red / (Blue + Green + Red + NIR + PAN)). This Ratio is stable and transferable. When in the classification process, this feature is applied on QuickBird, in the IKONOS image only a slight change in the value settings is necessary to adapt the process for both image types. There is no need to change the architectural process design when transferring the classification between these two sensor types. Only very few classes show deviating characteristics between the IKONOS and QuickBird sensors, what can be observed on the coniferous forest - which has a lot more textural characteristics in the QuickBird analysis than IKONOS.

The feature 2B (Fig. 2) is based upon neighborhood relationships (contrasting neighboring edges in the parking plot versus the building and the trees versus the meadow). Figure 2C (Fig. 2) shows the energy balance towards the sun, absorption versus reflection (the trees and the meadow versus the building and the parking plots). These two features are the main pillars of transferability of a rule set in multiple scene interpretation using a single architectural process.

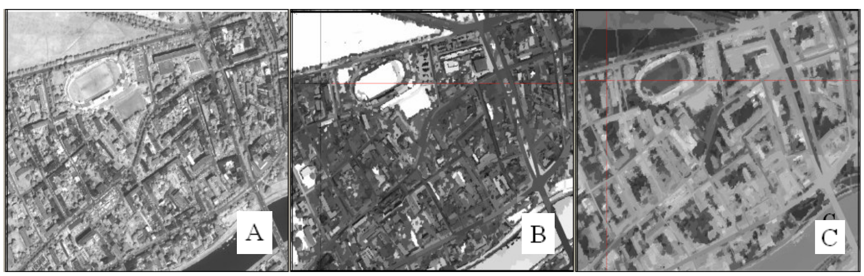

Fig. 2. A -The PAN band of VHRS image; B - The texture feature based upon edges and C - the ratio of Red band.

Another problem in urban analysis is the separation of open soil and sealed areas. Due to the texture analysis based upon edge detection (Musick et. al., 1991, Wężyk, et. al., 2005) open soil in agricultural fields are easier to separate. Edges as image objects play a crucial function in object detection. As Figure 1 (Fig. 1) show, the absence of a building marks itself due to the absence of edge influences. Spectral properties are not sufficient when vegetation does not replace previous built-up areas (like replacement by open soil).

5. ESSENTIALS IN PRE-PROCESSING

Essential in image pre-processing for larger areas is a split in segmentation parameters for objects that differ in texture. In step 7, all objects except the road (gathered from cadastral maps) are segmented with a scale factor = 100. (QuickBird scene). The texture map (Fig. 3 – upper right image “B” - the texture *Pan-BF*) show very homogeneous objects in white colour. The objects with many edges appear as dark-grey. The upper left image "A" shows the original PAN band.

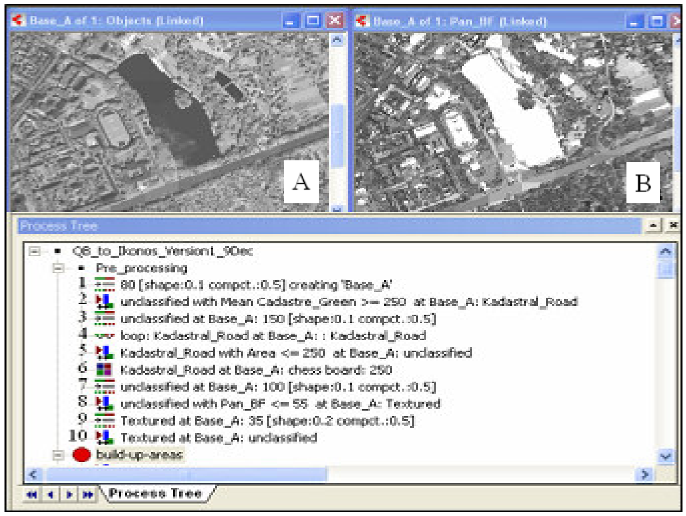

Fig. 3. The process-tree in pre-processing in DEFININES software..

The texture map *Pan-BF* is described in detail in Wężyk (Wężyk et. al., 2004, 2005). After classifying the texture in step 8, a more detailed segmentation parameter 35 is applied in step 9 only for high textured areas. The smooth areas such as water and grasslands do not need smaller area per object thus saving computing time and PC memory. The resulting high textured objects are made unclassified in step 10 to start the process with a clean object list. These last four steps show now, how irrelevant has become the discussion on the best scale parameter for a single image. In eCognition version 5 and higher, the scale parameter can be applied exactly towards the textural content of each image object.

6. RESULTS

The adopted OBIA classification hierarchy in this study is presented in the Table 1. The differences between Level 1 (9 land use classes) and Level 2 (22 classes) result from the precise of OBIA but also very important properties of the objects at the same time.

The area of the "greenness" (sum of: high vegetation: 24,99% + low vegetation: 44,31% + sport areas: 1,39%) is like 70,69 % of the whole Krakow municipality area (Fig. 4-7). The invested areas (17,42 %) together with roads infrastructure (3,48 %) and other heaps (0,84 %) cover almost one fifth (21,74 %) of the city (Tab 1).

Tab 1. Land use classes – Level 1 and 2 in the OBIA of VHRS of Krakow area.

Level 1		Level 2		Area	
ID	Class	ID	Class	[%]	[ha]
10	Invested areas	100	Buildings	1,39	505,63
		101	Roofs with homogenic surface	1,29	467,95
		102	Invested – very bright areas, concrete	0,39	140,96
		103	Invested – bright areas, low NDVI	1,61	583,75
		104	Invested – with out vegetation	1,52	552,09
		105	Invested – sharp edged	1,13	408,15
		106	Invested – revised from the cadastral map	1,17	424,99
		107	Invested – diversified texture	1,67	607,45
		108	Invested – high texture	1,35	491,82
		109	Invested – others	5,90	2 138,52
20	High vegetation	200	High vegetation	22,71	8 237,63
		201	High vegetation, others	2,28	825,48
30	Low vegetation	300	Meadows, pasture, low vegetation	16,90	6 129,29
		301	Low vegetation diversified	23,16	8 402,10
		302	Low vegetation – low NDVI	2,74	993,49
		303	Low vegetation – others	1,51	547,83
40	Sport	400	Sport and green areas, gardens	1,39	504,55
50	Water	500	Water basins, rivers	1,94	703,69
60	Roads	600	Roads infrastructure	3,48	1 260,63
70	Rubbish	700	Rubbish dumps, slag heap, open soil	0,84	304,39
80	Agriculture	800	Agriculture	5,35	1 939,04
90	Shadow	900	Shadow	0,28	100,15
Sum				100,00	36 269,58

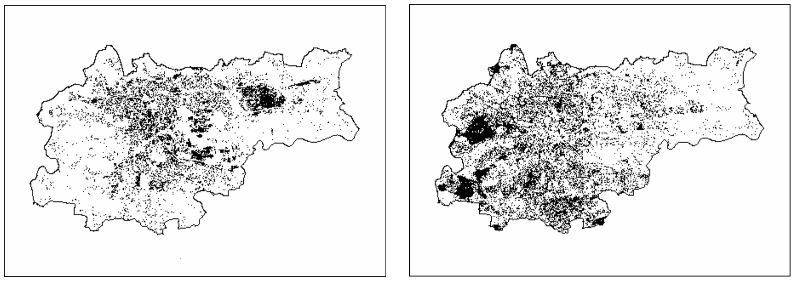

Fig. 4. Classes: “Invested areas” (ID=10) and “High vegetation” (ID=20)

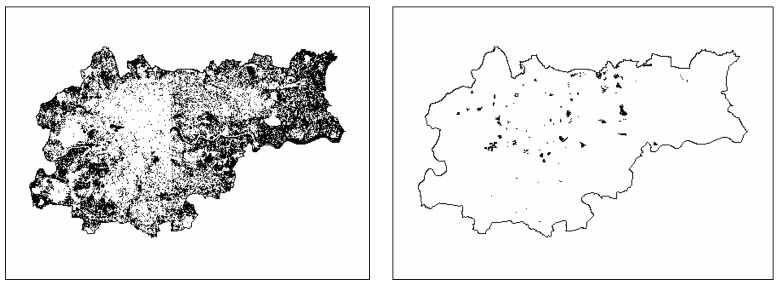

Fig. 5. Classes: “Low vegetation” (ID=30) and Sport green areas (ID=40)

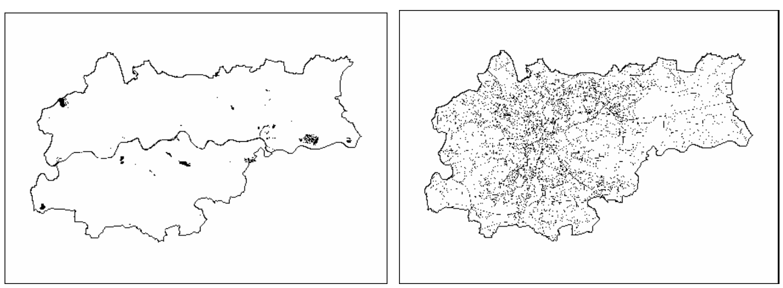

Fig. 6. Classes: “Water basin, river” (ID=50) and “Road infrastructure” (ID=60)

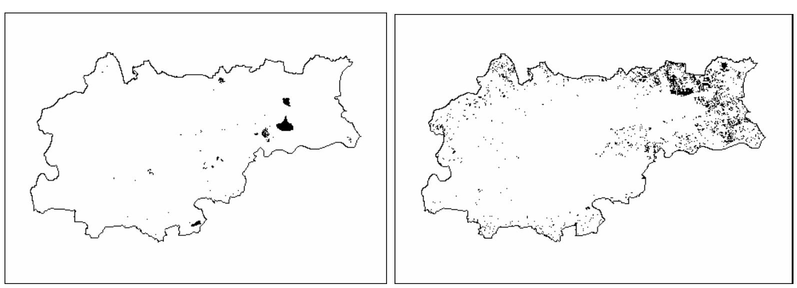

Fig. 7. Classes: “Rubbish dumps, slag heap” (ID=70) and “Agriculture” (ID=80)

7. CONCLUDING REMARKS

A standard protocol for feature extraction based upon image object analysis functions very well for scanned paper information (cadastral map) as well as for VHRS data.

Protocols developed for QuickBird analysis heavily depending upon the Ratio of Red for vegetation and presence/absence of edge objects allow stable and transferable design of these protocols. Both methods are derived from experimental process design in mainly forest analysis projects inside the Laboratory of GIS and Remote Sensing at the Agriculture University of Krakow. The experiments can now be successfully applied in commercial applications even outside the forest domain. Only small adaptations of the classification protocol build for eCognition 5 environments are necessary to analyses of Ikonos data with similar properties. The same protocols can now be used for every Polish city to prepare a basis for further urban analysis. Thus an existing eCognition process design is capable to be applied to many urban analysis projects without major alterations. This makes its applications much cheaper as it works like a kind of “universal tool” for urban analysis throughout Poland.

The role of VHRS data in the detailed inventory is much less important than in monitoring purposes. A full LiDAR inventory allows a data overkill situation in the presence of VHRS data but the role of VHRS data remains unbeatable in a monitoring situation. Data overkill however is very practical in an inventory stage preceding the monitoring phase when automatic protocols are used to classify the data.

The use of VHRS data in combination with LiDAR analysis, a situation which is now under construction, shows a regular approach which has left the Laboratory of GIS and RS at AUC to be deployed in a standard production process of GIS data base update of the Krakow municipality.

8. LITERATURE

de Kok R., Koziol K., Wężyk P., 2005. Application of Object Oriented Classification of QuickBird VHR satellite images and GIS spatial analysis in forest stand mapping. Annals of Geomatics. Vol. III, No 4. s. 99 -108.

de Kok R., Wężyk P., 2006. Process development and sequential image classification for automatic mapping using case studies in forestry. ISPRS WG VIII/11 & EARSeL joint Conference '3D Remote Sensing in Forestry', Vienna, 14-15 February. pp. 380-384.

Musick H.B., Grover H.D., 1991. Image textural measures as indices of landscape pattern. Quantitative methods in landscape ecology. Ed. by M.G. Turner and R.H. Gardner, Springer-Verlag, New York, pp. 77–103.

Wężyk P., de Kok R., 2005. Automatic mapping of the dynamics of forest succession on abandoned parcels in South Poland. In: Strobl, J., Blaschke T. & Griesebner G., Hrsg. Angewandte Geoinformatik zum 17. AGIT-Symposium Salzburg 2005, Wichman. Heidelberg, pp. 774-779.

Wężyk, P., de Kok R., Zajączkowski G., 2004. The role of statistical and structural texture analysis in VHRS image analysis for forest applications - A case study on QuickBird data in Niepolomice Forest. In: Strobl, J., Blaschke T. & Griesebner G., (Hrsg.): Angewandte Geoinformatik 2004. Beiträge zum 16. AGIT-Symposium Salzburg 2004, H. Wichman Verlag, Heidelberg, pp. 770-775.

Wężyk P., Pyka K., Jędrychowski I., 2006. Wpływ jakości numerycznego modelu terenu na wynik ortorektyfikacji wysokorozdzielczych obrazów satelitarnych Ikonos-2. Archiwum Fotogrametrii, Kartografii i Teledetekcji. Fotogrametria, Teledetekcja i GIS w świetle Kongresu ISPRS. Vol.16. s. 557-566.

USING THE OBJECT-BASED IMAGE ANALYSIS (GEOBIA) IN THE CLASSIFICATION OF THE VERY HIGH RESOLUTION SATELLITE IMAGES OF KRAKOW MUNICIPALITY

KEY WORDS: OBIA (Object Based Image Analysis), IKONOS, QuickBird, automation, land use

SUMMARY: Recent developments in Remote Sensing and GIS have reached maturity which allows to implement the research results into standardized process flows for updating and checking the municipality cadastral information. The database containing the city cadastre already handles data fusion methods itself. Available information considerably enhance information extraction from new data collections with high quality sensors such as LiDAR, photogrammetrical imagery and VHRS data. Huge amounts of available data must be processed in sequences to keep them handable. Transferable protocols for automatic handling of VHRS data can now be put into a full production process to assist the workflow of other image data from airborne platforms and integrate these GIS output into further cadastral GIS analysis. The data fusion within this project allows a highly detailed description of the city status-quo and the basis for change detection. Further these results are besides a very important archival inventory also a basis for decision support, now and in the future. The whole workflow was of a chain of previous research projects which were put into a commercial workflow. This study shows an experience report on, how the product chain was built-up and what type of products were delivered to the municipality of Krakow (Poland).

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