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Interpretation of LISS-III images obtained by fusion with panchromatic data

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ABSTRACT: Possibilities of visual interpretation of IRS-1C satellite images are presented in the article. Analyses were done for four colour composites: two of them were prepared as combinations of LISS-III channels – LISS(4,5,3) of channels (4,5,3), LISS(NAT) of channels (3,2,"synthetic blue") and the remaining two were formed from merging LISS-III composites with panchromatic image – LISS(4,5,3)+PAN, LISS(NAT)+PAN. LISS(NAT) composite prepared in almost natural colours, was produced with the use of "synthetic blue" band generated by Euromap GAF company. Interpretation of land cover and land use forms was done in accordance with the modified CORINE legend – Level 4th and its results were compared with reference aerial photographs. The obtained results were presented in the form of table including correctness of interpretation (in percent). In case of LISS(4,5,3) composite 84.75% accuracy was obtained, while for LISS(NAT) composite only 72.69% accuracy was achieved. Low degree of interpretation accuracy in case of LISS(NAT) composite was caused first of all by tonal uniformity of image with almost natural colours. When merging LISS-III composite with IRS-1C panchromatic image, substantial increase of interpretation accuracy was reached: 89.84% for false-colour composite and 87.54% for composite with almost natural colours. Incorporation of panchromatic band allowed for significant increase of interpretation of built-up areas. In case of natural colours also classes related to forests and semi-naturals ecosystems were much better recognized.

1 INTRODUCTION

This paper is the continuation of presentation of the results obtained in the course of project „Preparation of the method for deriving image information for making detailed land use maps" financed by the Polish State Committee for Scientific Research.

First part of the results, concerning interpretation of LISS-III satellite images, was presented during 22nd EARSeL Symposium in Prague (Lewinski & Polawski 2003, Lewinski & Polawski 2002). Authors present in this paper the successive results achieved on the basis of visual interpretation of Indian satellite images. Four types of transformations were taken into analysis: false-colour LISS 4,5,3 composite, natural colour LISS-III composite, and these two types of composite merged with panchromatic image. Interpretation of satellite images was done for study area located within Legionowo district. Land cover and land use forms were interpreted using legend prepared at the Institute of Geodesy and Cartography (Polawski, 2002), which is modification of CORINE legend. Interpretation was done directly on the monitor screen in GeoMedia environment.

The detailed land cover/land use map, prepared for Legionowo district on the basis of aerial photographs, was the reference material for evaluation of interpretation of satellite images.

The obtained results are presented in the form of table, which includes for each class and for each composite accuracy of interpretation.

2 STUDY AREA

Legionowo district (Mazowieckie voivodship), was selected as a study area. It is located in the central part of Mazowiecka Lowland in the confluence of Narew and Vistula rivers, adjoining Warsaw agglomeration. It covers 39 278 ha, being composed from five communes: Legionowo, Serock, Jablonna, Wieliszew and Nieporet. Legionowo is the main city of the district (50 000 inhabitants); its distance to the center of Warsaw is only 25 km.

The study area comprises both elements of environment classified as protected landscapes (they belong to the Warsaw Zone of Protected Landscape), as well as transformed areas, created mainly as a result of impact of agglomeration. Characteristic feature of Legionowo district is Zegrzynski Water Reservoir, covering 3300 ha, created as a result of constructing dam on Narew river. Within the district there are both forests and semi-natural ecosystems, wetlands, as well as anthropogenic areas. Besides dominant contribution of arable land and grassland to land use types there are also quite large forest areas, covering over 33% of the district. Anthropogenic elements also appear at Legionowo district, with prevailing low-density housing of urban type.

Taking into account diversity of existing forms of land use Legionowo district can be considered as administrative unit typical for Polish conditions of land utilization.

3 MATERIALS

All interpretation works were done using the transformed IRS-1C satellite images: LISS-III multispectral image and panchromatic image, collected on September 30, 2000. Synthetic blue band generated by Euromap company on the basis of LISS-III channels (Euromap 2002) was also used. This band, corresponding to blue spectral range allows for making colour composite in almost natural colours.

Evaluation of results of satellite image interpretation was done through comparison with aerial photographs, which were the basis for preparing detailed land use database. Colour aerial photographs at a scale of 1:26000, taken in May 2001, were used for this purpose. Utilizing 54 photographs orthophotomap covering 90% of Legionowo district was prepared. Considering resolution of satellite images, pixel size of aerial photographs was decreased from 0.5 to 1 m.

4 PREPARATION OF IRS-1C IMAGES FOR INTERPRETATION

Interpretation of land cover and land use forms was done on the basis of four transformations of satellite images obtained through application of LISS-III and panchromatic images:

- LISS(4,5,3) – colour composite obtained with the use of algorithm eliminating lower resolution (70 m) of channel 5 (Lewinski & Polawski 2003, Lewinski & Polawski 2002)
- LISS(NAT) – colour composite with almost natural colours obtained with the use of synthetic blue band, composite (3,2,"synthetic blue")
- LISS(4,5,3)+PAN – colour composite formed through merging of LISS(4,5,3) and panchromatic image
- LISS(NAT)+PAN – colour composite formed through merging of LISS(NAT) and panchromatic image

Satellite images were transformed in such a way, to facilitate precise visual interpretation. In the course of geometric correction size of pixel of LISS-III and panchromatic images was set to 21 and 4 meters, respectively. Cubic convolution resampling method was applied in these works.

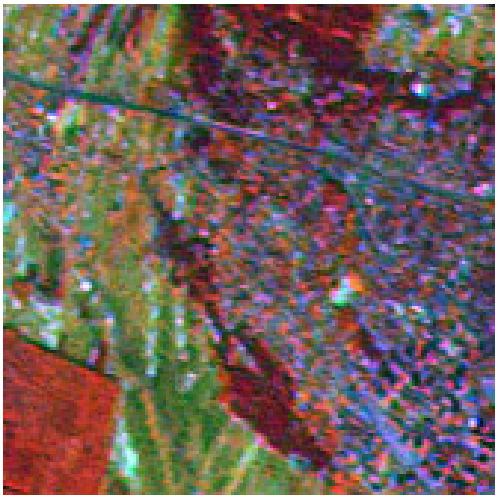

Figure 1. LISS(4,5,3) colour composite

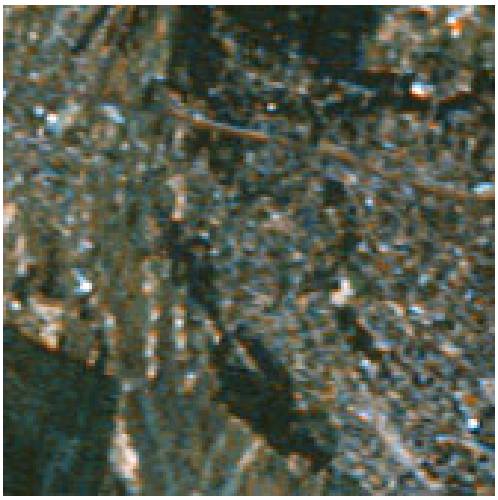

Figure 2. LISS(NAT) colour composite

Figure 3. LISS(4,5,3)+PAN colour composite

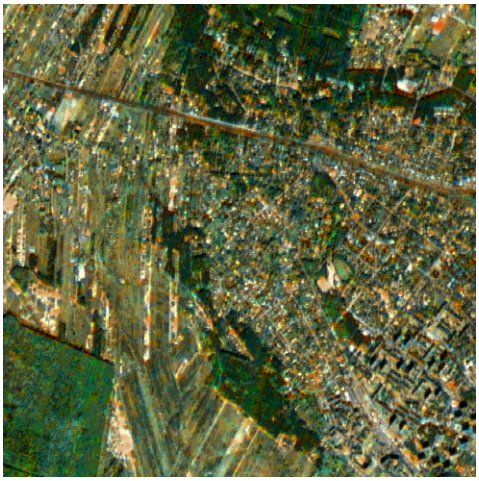

Figure 4. LISS(NAT)+PAN colour composite

Merging of LISS-III colour composites with panchromatic image was done using the commonly known RGB/IHS/RGB transformation (Jensen 196, Wald 2002). Fragments of the transformed satellite images were presented in figures 1, 2, 3 and 4.

5 INTERPRETATION PRINCIPLES

It was assumed as interpretation principle to distinguish objects with minimal size equal to 1 ha, i.e. 100x100 m (2x2 mm on 1:50 000 image). The same level of detail was assumed for interpretation of colour Phare aerial photographs (Polawski, 2002).

If the same interpretation assumptions would be done for all land use and land cover classes, it could result in loosing objects , which belong to dispersed urban areas. So, in case of urban classes it was assumed to distinguish objects with smaller dimensions: 1x1 mm on 1:50 000 image.

Visual interpretation of satellite images was done on the basis of the transformed colour composites. 1:50 000 and 1:25 000 topographic maps were used as supporting materials.

6 ANALYSIS OF RESULTS OF INTERPRETATION OF LAND USE AND LAND COVER FORMS

Evaluation of visual interpretation of land use and land cover forms was done for four transformations of satellite images: LISS(4,5,3), LISS(NAT), LISS(4,5,3)+PAN and LISS(NAT)+PAN. Interpretation was performed for the study area located within Legionowo district. The obtained results were compared with aerial photographs, being reference material in these works. From technical point of view polygons belonging to two databases were intersected.

Table 1 includes quantitative comparison of interpretation possibilities of the analyzed satellite image composites. For each class degree of correctness of interpretation (in percent) is given; it is determined through comparison with aerial photographs. Also correctness of interpretation is given in relation to the CORINE Level 1 legend, represented by built-up areas, agricultural land, forests and semi-natural ecosystems, wetlands and water.

Total accuracy of interpretation of LISS(4,5,3) composite is 84.75%. Out of 37 land cover/ land use forms 20 of them were recognized with 90-100% accuracy, while four land cover types were unrecognizable.

It can be seen from figure 1 and 2, that in case of colour composite with almost natural colours, when comparing with false-colour (4,5,3) composite, general suppression and tonal smoothing of the image appears. Lack of sharp boundaries between particular land cover forms makes is discrimination much more difficult. These preliminary remarks are confirmed by results of interpretation. It can be found in table 1, that general accuracy of delineations of land cover and land use forms on the basis of LISS(NAT) composite reached 72% and is lower over 12% when comparing with results of interpretation of LISS (4,5,3) composite. Tonal smoothing of LISS (NAT) image has significant impact first of all recognition of forests and semi-natural ecosystems, as well as wetlands. LISS-III composite with almost natural colours does not improve interpretation possibilities of land cover/land use forms, even making quite often their interpretation more difficult.

Table 1. Quantitative evaluation of interpretation of satellite images

CORINE Level 1	LAND COVER AND LAND USE CLASSES (CORINE Level 4 nomenclature)	COLOUR COMPOSITE OF IRS-1C IMAGE			
		LISS(4,5,3)	LISS(NAT)	LISS(4,5,3) + PAN	LISS(NAT) +PAN
		[%]	[%]	[%]	[%]
Built-up areas	1.1.2.1. Discontinuous urban built-up areas with apartment blocks	0	0	99,99	96,87
	1.1.2.2. Discontinuous urban built-up areas	50,39	51,66	48,20	51,14
	1.1.2.3. Discontinuous urban built-up areas with family houses	99,00	91,16	81,36	90,74
	1.1.2.4. Rural built-up areas with family houses	72,97	54,74	72,97	97,12
	1.1.2.5. Summer residential areas	48,52	53,67	85,37	98,88
	1.2.1.1. Industrial areas	98,55	98,55	98,41	100
	1.2.1.3. Areas with special technical infrastructure	100	100	100	100
	1.2.1.5. Public buildings	0	0	0	0
	1.3.1.1. Mineral extraction sites (sand, gravel)	100	100	100	100
	1.3.1.4. Reclaimed extraction sites (partly covered with vegetation)	100	100	100	100
	1.3.2.2. Liquid waste dumps	75,92	74,33	75,92	79,94
	1.3.3.1 Construction sites	81,37	83,22	81,37	85,68
	1.4.1.1. City and rural parks	89,08	100	89,08	99,71
	1.4.1.3. Garden plots	100	50,90	100	100
	1.4.1.5. Cemeteries	100	100	100	100
	1.4.1.6. Wasteland	100	99,88	84,22	100
	1.4.2.1. Sport areas	100	100	67,92	100
	1.4.2.3. Leisure/camping areas	0	0	0	0
	Total (CORINE Level 1)	**59,18**	**57,25**	**81,8**	**85,32**
Agri-cultural land	2.1.1.1 Arable land	98,59	99,23	96,68	99,30
	2.1.1.3. Greenhouses	21,89	49,49	94,76	58,25
	2.2.2.1. Orchards	90,61	84,02	94,09	96,54
	2.3.1.1. Grassland	97,67	96,84	97,61	97,28
	2.3.1.2. Grassland with trees and shrubs	88,14	69,32	88,14	99,55
	Total (CORINE Level 1)	**93,78**	**91,76**	**95,75**	**96,95**
Forests and semi-natural eco-systems	3.1.1.1. Deciduous forests with continuous canopy	86,90	16,07	86,90	73,00
	3.1.1.2. Deciduous forests with discontinuous canopy	93,46	11,72	93,46	13,26
	3.1.2.1. Coniferous forests with continuous canopy	92,60	79,13	92,59	90,63
	3.1.3.1. Mixed forests with continuous canopy	89,58	81,05	89,58	78,59
	3.1.3.2. Mixed forests with discontinuous canopy	0	0	0	0
	3.2.4.2. Afforestations – man-made and natural	62,99	0	62,96	20,20
	3.2.4.3. Deforestations and clear-cuts	100	**100**	**100**	100
	3.3.1.1. Beaches	100	100	100	100
	3.3.1.4. River sandbanks	77,57	100	77,57	100
	3.3.3.1. Sparse vegetation on sands	100	100	100	100
	Total (CORINE Level 1)	**90,11**	**67,94**	**90,1**	**82,91**
Wetlands	4.1.1.1. Inland marshes	100	55,66	100	72,41
	Total (CORINE Level 1)	**100**	**55,66**	**100**	**72,41**
Water	5.1.1.1. Rivers	99,04	99,03	99,07	100
	5.1.2.1. Natural water bodies - lakes	52,07	54,69	52,10	79,94
	5.1.2.4. Excavations and hollows filled with water	100	82,41	100	100
	Total (CORINE Level 1)	**90,65**	**87,27**	**90,48**	**96,37**
	TOTAL ACCURACY OF INTERPRETATION	**84,75**	**72,69**	**89,84**	**87,54**

Merging of multispectral and panchromatic images caused enhancement and improvement of general interpretability of colour composites. LISS (4,5,3) +PAN composite reveals higher level of detail, inner structures of some land cover forms are more readable. Contribution of panchromatic image caused increase of accuracy of interpretation to over 89%. The highest improvement (over 22%) was obtained within urban areas. It can be especially observed in case of discontinuous urban built-up areas with apartment blocks (class 1.1.2.1). Inclusion of panchromatic image caused, that this land cover urban form is well readable on colour composite. Distinct improvement of recognition of summer residential areas (class 1.1.2.5) was also observed. In case of the remaining land use and land cover forms, which exist within built-up areas, generally high accuracy of interpretation was not distinctly increased; it is similar to levels achieved for LISS-III composite. For agricultural land slight improvement of interpretation accuracy can be observed; especially in case of greenhouses. The applied type of transformation did not cause higher interpretability of forest structure and recognitions of tree species is similar

to that obtained for LISS(4,5,3) composite. The same applies to wetlands and water.

LISS(NAT)+PAN composite became distinctly more readable, as in case of LISS(4,5,3)+PAN composite. It was confirmed by the results included in table 1; general accuracy of interpretation is high, reaching 87.54%. Panchromatic channel significantly increased readability of some elements visible on colour composite, making it more "friendly" for visual interpretation. In case of urban areas high level of accuracy of interpretation was achieved – 85%. It is especially evident for discontinuous urban-rural areas with family houses and summer residential areas. However, still exist some difficulties, as for the remaining composites, in precise delineation of discontinuous urban built-up areas (class 1.1.2.2). Level of interpretation accuracy for agricultural land does not change. The same applies to forests. Still some difficulties exist in estimating canopy closure in forests; it can be especially visible in case of deciduous forests with loose canopy closure. The conducted analysis revealed, that partly these forests are interpreted as grassland with trees and shrubs (class 2.3.1.2). Certain decrease can be observed in precise delineation of wetlands, while water areas are well distinguishable. In contrary to pure LISS(NAT) composite, when it is enriched with panchromatic channel, its interpretation possibilities can be compared with false-colour composite. It is especially important, if satellite images are analyzed by persons who are not specialized in remote sensing.

There is in table 1 class called "Public buildings (1.2.1.5). This class is derived from the level of detail of the accepted legend; it exists within study area. However it cannot be correctly recognized on the basis of colour composites and topographic maps. Hence for all four analyzed composites zero level of recognition of this class was given.

7 CONCLUSIONS

Correctness of interpretation of land cover and land use forms reached 84.75% for false-colour composite – LISS(4,5,3), while 72.69% for composite with almost natural colours – LISS(NAT).

Tonal smoothing of LISS(NAT) image has significant impact on level of distinguish ability of forests and semi-natural ecosystems, as well as wetlands.

Natural colours do not increase interpretation possibilities of land cover/land use forms, making frequently their interpretation more difficult.

After merging LISS-III colour composite with panchromatic image distinct improvement of class recognition was achieved: 89.84% for LISS(4,5,3) +PAN composite and 87.54% for LISS(NAT)+PAN composite.

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