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Evaluation of interpretation possibilities of LISS-III satellite images

St. Lewinski & Z.F. Polawski
Institute of Geodesy and Cartography, Warsaw, Poland

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ABSTRACT: The main goal of the paper is to present the interpretation possibilities of LISS-III images. Evaluation was made on the basis of the analysis of visual interpretation of colour RGB composite [4,5,3]. It has been proved that this composite enables optimal recognition of land cover forms. The area of research is Legionowo district characterised by the presence of the majority of land cover forms typical for Polish landscape. Class division was made on the basis of the extended legend of CORINE programme (level 4). Land cover interpretation on the basis of aerial photographs was used as a reference material.

This work presents the method of processing colour RGB composite [4,5,3] that reduces the effect of low resolution (70 m) of the fifth spectral channel (shortwave IR) of LISS-III images. The application of IHS algorithm makes it possible to create colour composite including low resolution channel 5 with details characteristic for channels with higher resolution.

On the basis of the results obtained it was found that the proposed type of transformation of LISS-III satellite image enables to achieve total reliability of 85.36%. Good results in land use / land cover interpretation were obtained for arable land group (91.37%), forests and semi-natural ecosystems (90.66%), wetlands (100%) and water bodies (90.65%). Non-satisfactory results were obtained in case of urban forms of land use / land cover (60.81%). Low differentiation in colour and photo texture between particular classes of anthropogenic areas is the main reason of weak recognition in this category. In addition, urban classes often differ only in function, but not in physiognomy. Difficulties in recognition on satellite images of built-up areas result from high differentiation of land elements forming this class and from relatively low resolution of satellite images.

1 INTRODUCTION

The authors present some results obtained within the research project "Preparation of the method for deriving image information for making detailed land use maps", financed by the Polish State Committee for Scientific Research. This project is aimed at evaluation of usefulness of LISS-III images collected by Indian satellite for interpretation of land cover forms.

Research works were conducted for the study area – Legionowo district, located in the vicinity of Warsaw.

Before beginning interpretation process, the selected LISS-III colour composite was adequately processed, in such a way, to obtain maximum information content.

Interpretation of land cover / land use forms was done visually (on the monitor screen); information content of satellite images was divided into categories, according to CORINE legend – Level 4.

As a reference material detailed land use database, prepared on the basis of aerial photographs, was applied.

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 centre of Warsaw is only 25 km.

The study area comprises both elements of environment classified as protected landscapes (they be-

long 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. In author's opinion results obtained within this study can be representative for the whole country.

3 MATERIALS

Evaluation of interpretation possibilities of land use forms on multispectral satellite LISS-III images was done on the basis of data collected by IRS-1C satellite on September 30, 2000.

LISS-III scanner registers image of Earth's surface in four channels, numbered from 2 to 5: channel 2 – green, channel 3 – red, channel 4 – near infrared, channel 5 – short-wave infrared radiation. Spectral ranges of particular channels are almost the same, as for Landsat Thematic Mapper channels 2, 3, 4 and 5.

LISS-III scanner has ground resolution of 23.5 m for channels 2, 3, 4 and 70 m for channel 5. Satellite data users receive data with pixel size resampled to 25 m for all four channels. Radiometric resolution is 7 bits, i.e. 128 grey levels (Landsat TM – 8 bits).

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 1:26 000, taken in May 2001, were used for this purpose. Utilizing 54 photographs orthophotomap covering 90% of Legionowo district was prepared. In order to make model orientation, 10 ground control points were used; their positions were measured with GPS technique. For x, y coordinates 0.5 m accuracy, while for z coordinate 1 m accuracy was achieved,. Considering resolution of satellite images, pixel size of aerial photographs was decreased from 0.5 m to 1 m.

4 PROCESSING OF LISS-III SATELLITE IMAGE

Interpretation of LISS-III satellite images was performed on the colour RGB composite of channels 4, 5 and 3. The choice of channels for colour composite was based on the analysis of information capacity of individual channels with the use of Optimum Index Factor (OIF) (Chavez et. al. 1982).

Taking four raw LISS-III channels new four sets of data were created; each of these sets contained three non-repeating channels. Next OIF for each set was calculated. The highest OIF value characterizing the largest information capacity was obtained for the set, composed from channels 3, 4 and 5. On the basis of the selected channels six color composites were prepared and next evaluated from the point of view of interpretation of land use / land cover. Two RGB composites - [4,5,3] and [5,4,3] proved to be the best; finally [4,5,3] composite, which is widely used in interpretation of land use on Landsat TM images, was selected.

Rectification of LISS-III images was the next stage of the processing. It was done using as a reference material orthophotomap prepared from aerial photographs. Satellite image was transformed with the use of cubic convolution resampling method. As a result of the experiments it was found, that optimum pixel size should be 21 m. Smaller pixel size does not improve quality of colour composition; image starts to be less sharp.

Composite formed from channels 4, 5 and 3 is the best from the point of view of information capacity. However, the contribution of low-resolution (70 m) channel 5 is clearly visible on the composite and makes visual interpretation difficult. An algorithm based on transformation between RGB and IHS colour systems has been applied to improve the interpretability of the [4,5,3] composite. The resulting composition is enriched by details characteristic for composite [4,3,2]. First for both composites [4,5,3] and [4,3,2]; Intensity, Hue and Saturation channels are generated. Next [4,5,3] composite is re-created from IHS colour system using Intensity channel taken from [4,3,2] composite. The transformed image is free of impact of low-resolution channel and simultaneously retains colours of the initial image (Lewinski 2000, Lewinski 2001).

As a result of all applied transformations the image with higher degree of detail was obtained, ensuring optimum of interpretation possibilities. In figure 1 original [4,5,3] composite is presented, while figure 2 demonstrates the image prepared for interpretation – obtained in the course of the described transformations.

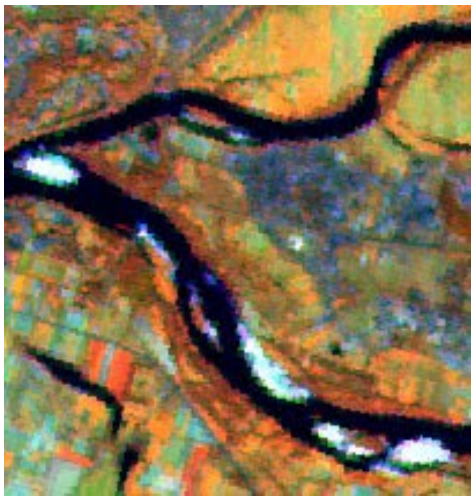

Figure 1. Original [4,5,3] composite of LISS-III image

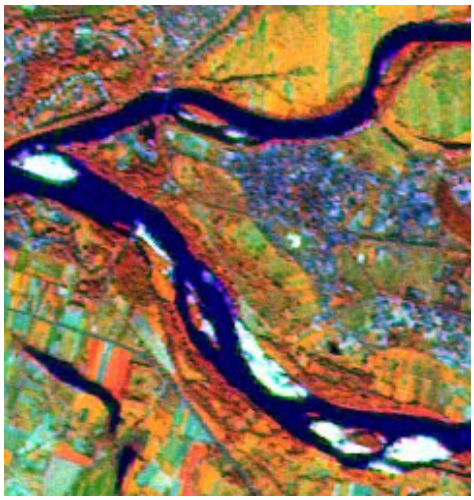

Figure 2. Improved [4,5,3] composite.

5 INTERPRETATION

The most important part of analysis of satellite image is to determine its relations with phenomena on Earth's surface. Information contained in satellite image is derived from three elements, which are the direct photointerpretation features:

- colour dependent on selection of composite of multispectral image
- photo structure, formed from homogeneous image elements, as far as colour, shape and size is concerned
- photo texture, being the spatial arrangement of structural image elements.

Interpretation features are closely related to spatial, spectral and radiometric resolution of the image.

Interpretation of aerial photographs and satellite image was done on the monitor screen in GeoMedia software environment. Two databases including boundaries, codes and attributes of delineations were created. As a result of the analyses it was decided, that land use forms will be interpreted with 1 ha accuracy. It means, that on 1:50 000 images the smallest units will have size 2 x 2 mm. Land cover / land use forms were interpreted in accordance with the rules determined by CORINE legend – Level 4 (Polawski 2002). This legend is more detailed and adapted to Polish conditions version of CORINE Level 3 legend (CORINE 1993).

Interpretation of aerial photographs was done for the whole area presented on orthophotomap, while for satellite images the selected, representative test sites were interpreted. 30 different land cover / land use forms were distinguished within Legionowo district.

6 QUALITATIVE AND QUANTITATIVE ANALYSIS OF RESULTS OF INTERPRETATION OF LISS-III IMAGE

Results of visual interpretation of LISS-III satellite image, referred to verification areas, were the subject of studies. Analysis comprised among others quantitative and qualitative evaluation of correct delineation of particular land cover / land use forms. It was based on comparing results of visual interpretation of satellite image with interpretation of aerial photograph, being the reference material. From technical point of view it was intersection of two databases. Such a procedure allowed for:

- comparison of areas of classes distinguished on satellite image and aerial photograph
- determination of classes (delineated on aerial photograph), which appeared within boundaries of classes on satellite image.

Quantitative verification of the results of visual interpretation of LISS-III satellite image was based on comparing area of particular land cover / land use class existing within verification polygon with area of the same class on aerial photograph. Results of this comparison are presented in table 1.

Table 1. Quantitative evaluation of visual interpretation of land cover / land use forms based on analysis of LISS-III satellite images

CORINE Level 1	Interpretation accuracy on satellite image Area of delineations on LISS-III image Area of delineations on aerial photograph Land cover and land use classes – CORINE Level 4	[ha]	[ha]	[%]
1	1.1.2.1. Discontinuous urban built-up areas with apartment blocks	125.24	-	-
	1.1.2.3. Discontinuous urban built-up areas with family houses	24.53	24.52	99.00
	1.1.2.4. Rural built-up areas with family houses	40.80	29.79	73.01
	1.1.2.5. Summer residential areas	29.43	14.28	48.52
	1.2.1.1. Industrial areas	48.50	47.80	98.55
	1.2.1.3. Areas with special technical infrastructure	53.81	53.81	100.00
	1.2.1.5. Public buildings	8.02	1.82	22.69
	1.3.1.1. Mineral extraction sites (sand, gravel)	20.35	20.35	100.00
	1.3.1.4. Reclaimed extraction sites (partly covered with vegetation)	36.91	36.91	100.00
	1.3.2.2. Liquid waste dumps	17.61	13.37	75.92
	1.3.3.1 Construction sites	27.44	22.43	81.74
	1.4.1.1. City and rural parks	3.39	3.02	89.08
	1.4.1.3. Garden plots	10.00	10.00	100.00
	1.4.1.5. Cemeteries	7.49	7.49	100.00
	1.4.1.6. Wasteland	25.87	25.87	100.00
	1.4.2.1. Sport areas	7.39	7.39	100.00
	1.4.2.3. Leisure/camping areas	37.52	-	-
2	2.1.1.1 Arable land	231.74	213.22	92.00
	2.1.1.3. Greenhouses	23.70	5.19	21.89
	2.2.2.1. Orchards	62.43	56.60	90.66
	2.3.1.1. Grassland	294.33	287.16	97.56
3	2.3.1.2. Grassland with trees and shrubs	88.11	77.76	88.25
	3.1.1.1. Deciduous forests with continuous canopy	234.03	201.07	85.91
	3.1.1.2. Deciduous forests with discontinuous canopy	7.35	6.87	93.46
	3.1.2.1. Coniferous forests with continuous canopy	836.19	782.86	93.62
	3.1.3.1. Mixed forests with continuous canopy	398.10	356.14	89.45
	3.1.3.2. Mixed forests with discontinuous canopy	5.76	-	-
	3.2.4.2. Afforestations – man-made and natural	15.24	9.60	62.99
	3.2.4.3. Deforestations and clear-cuts	6.70	6.70	100.00
	3.3.1.1. Beaches	3.63	3.63	100.00
	3.3.1.4. River sandbanks	6.42	4.98	77.57
	3.3.3.1. Sparse vegetation on sands	3.18	3.18	100.00
4	4.1.1.1. Inland marshes	4.24	4.24	100.00
5	5.1.1.1. Rivers	80.42	79.65	99.04
	5.1.2.1. Natural water bodies - lakes	19.51	10.16	52.07
	5.1.2.4. Excavations and hollows filled with water	8.32	8.32	100.00

It results from the above presented data, that within 17 categories classified as urban areas, seven of them were classified with 100% correctness. These are: areas of technical infrastructure (1213), mineral extraction sites (1311 and 1314), garden plots (1413), wasteland (1416), sport areas (1421).

The highest error in interpretation occurred in case of two classes: discontinuous urban built-up areas with apartment blocks (1121) and leisure/camping areas (1423).

In case of summer residential areas (1125) reliability of interpretation was 48.52%, while public buildings (1215) were recognized correctly with

22.69% accuracy (table 1). This situation is caused by many factors, among others photomorphic character of anthropogenic and urban-rural areas plays here the crucial role. It makes, that particular forms of land use / land cover due to size of satellite pixel and spectral similarity are not recognizable.

Anthropogenic areas are recognized with low accuracy also due to fact, that they differ only from functional (not physiognomic) point of view. Particular categories often have similar physiognomic features, and their classification depends on their function (for instance public buildings (1215)).

Results of qualitative analysis concerning the selected land use / land cover forms seem to confirm these relations (table 2). For instance it can be seen, that discontinuous urban built-up areas with family houses (1123) also included discontinuous urban built-up areas with apartment blocks (1121), as well as public buildings (1215) and sport areas (1423).

In case of summer residential areas (1125), as it can be seen from table 3, almost 50% of total area of this category was classified correctly. The rest of verification polygon was classified as grassland (2311), grassland with trees (2312) and deciduous forests with discontinuous canopy (3112). Public buildings (1215) were classified in 75% as built-up areas with family houses (1123). It was not possible to distinguish leisure areas (1423) on the LISS-III satellite image. Verification polygon was classified as built-up areas with family houses (1123), grassland (23112) and deciduous forests (3112).

As far as arable land is concerned, degree of recognition of particular land use / land cover forms varied from 21.89% in case of greenhouses (2113) to 97.56% for grassland (2311) (table 1). Low recognition of greenhouses, which were mostly classified as arable land (56.7) is caused mainly by small area of this land cover form. In many cases (21.35%) greenhouses were recognized as built-up areas, due to similar spectral characteristics of both land use / land cover forms.

Quite good results were achieved in correct recognition of forests and semi-natural ecosystems. Low recognition of mixed forests with discontinuous canopy (3132) is visible (table 1); it was caused by heterogeneity of this class and resolution of satellite image.

Wetlands and water bodies were well recognized, in most cases with 100% accuracy (table 1). Only natural water reservoirs (5121) are characterized by lower recognition; it can be explained by small reservoirs, which are not visible on satellite image and by errors in interpretation of lake boundaries covered with vegetation.

Table 2. Qualitative evaluation of interpretation of LISS-III images for the selected category " discontinuous urban built-up areas with apartment blocks" (1123)

aerial photograph	LISS-III satellite image: discontinuous urban built-up areas with family houses (1123))	
	area	
	[ha]	[%]
Discontinuous urban built-up areas with apartment blocks (1121)	125.24	73.00
Discontinuous urban built-up areas with family houses (1123)	24.52	14.30
Public buildings (1215)	6.19	3.60
Leisure/camping areas (1423)	15.6	9.10
Total	171.55	100.00

Table 3. Qualitative evaluation of interpretation of LISS-III images for the selected classes

aerial photograph	LISS-III satellite image: Summer residetial areas (1125)		Public builings (1215)		Leisure areas (1423)	
	area					
	[ha]	[%]	[ha]	[%]	[ha]	[%]
Built-up areas with apartment blocks (1121)	-	-	-	-	-	-
Built-up areas with family houses (1123)	-	-	6.20	77.31	15.61	41.62
Summer residential areas (1125)	14.28	48.52	-	-	-	-
Public buildings (1215)	-	-	1.82	22.69	-	-
Leisure areas (1423)	-	-	-	-	-	-
Grassland (2311)	10.65	36.18	-	-	9.41	25.07
Grassland with trees (2312)	1.66	5.64	-	-	-	-
Deciduous forests with discontinuous canopy (3121)	2.84	9.66	-	-	12.5	33.31
Total	29.43	100.00	8.02	100.00	37.52	100.00

7 CONCLUSIONS

Evaluation of interpretation possibilities of LISS-III image was done for land use / land cover forms. Results of interpretation of satellite image were compared with those obtained from aerial photographs. Two types of evaluation were done: quantitative and qualitative.

On the basis of the obtained results it was found that the proposed type of transformation of LISS-III satellite image enables to achieve total reliability of 85.36% (see table 4). Good results in land use / land cover interpretation were obtained for arable land group (91.37%, forests and semi-natural ecosystems (90.66%), wetlands (100%) and water bodies (90.65%).

Non-satisfactory results were obtained in case of urban forms of land use / land cover (60.81%). Low differentiation in colour and photo texture between particular classes of anthropogenic areas is the main reason of weak recognition in this category. In addition, urban classes often differ only in function, but not in physiognomy. Difficulties in recognition on satellite images of built-up areas result from high differentiation of land elements forming this class and from relatively low resolution of satellite images.

It is planned to make within the presented project evaluation of usefulness of LISS-III image merged with panchromatic mage for interpretation of land cover, as well as comparison with the interpreted Landsat TM image.

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Table 4. Final evaluation of land use / land cover classification on the basis of visual interpretation of LISS-III satellite image

Aggregated forms of land use / land cover (CORINE –Level 1)	Sum of areas of verification polygons on aerial photograph [ha]	Sum of areas of polygons on LISS-III image [ha]	Correctness of interpretation of LISS-III image [%]
1. Urban areas	524.30	318.85	60.81
2. Agricultural areas	700.31	639.93	91.37
3. Forests and semi-natural ecosystems	1516.60	1375.03	90.66
4. Wetlands	4.24	4.24	100.00
5. Water bodies	108.25	98.13	90.65
Total	2853.70	2436.18	85.36