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FOREST MAP REVISION USING THE HYPERSPECTRAL SCANNER AISA IMAGES

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ABSTRACT

Taking decisions in the Polish State Forests is supported by the using of the attribute database SILP (Information System of State Forests) and digital forest maps (LMN), as well as by generation of selected thematic maps. The hyperspectral images are a rich source of the objective, precise, and quickly available information about the forest. A complex nature of the forest ecosystem requires usage of images containing not only geometrical (shape, size, coordinates) information, but also about spectral characteristics of single forest stands. The purpose of this study was to determine the usefulness of a high resolution (1 x 1 m; 32 channels) hyperspectral scanner AISA for revision and updating of the digital forest map and SILP database of Niepolomice Forest near Krakow (southern Poland).

AISA images proved highly useful in identification of coniferous and broadleaf stands, and also of non-forest areas (grass vegetation). It was possible on their basis to delineate the homogeneous parts of the image, which are a basic requirement for creating and verifying a forest division into compartments. It was also possible to determine some stand characteristics, such as: the crown cover density or stand mixture (cluster, belt etc). The integration of airborne scanners images in to the GIS, and their practical use for new forest management plans give the opportunity to support the inventory field work or forest monitoring.

INTRODUCTION

A rational management of forest resources, expressed in the first place by their balanced utilization and care to increase their biodiversity, requires a deliberate administration in space and time. In Europe since 19 the century forest management provides information being the basis for creation of specific rules, instructions, and management plans for the forest areas. In Poland at the present time the methods of forest inventory are defined by the Instruction of Forest Management (i), which also defines various kinds of forest maps (understood as the visualization of the management plan §1. pnt 15). The generating and use of thematic maps require functioning of the system GIS based on the updated bases of geometrical and attribute data connected by relations.

In Poland, forests make about 28.4 % of the country's area, i.e. almost 8.9 million ha (ii), and 80 % of them is under ownership of the State Forest – National Forest Holding. In respect of administration the forest area is divided into 17 Regions, each administered by the Regional Directorate of State Forests. The Regions are divided into Forest Districts (430 in total), and in each forest district there are several Forest Ranges (about 5000 in total).

Since 1977 the Information System of State Forests (SILP) has been functioning in all forest districts. One of its modules is the database „LAS" storing the attribute data obtained during forest inventory (every 10 years). Work on implementation of the digital forest maps (LMN) in Polish State Forests was initiated in the 1990s, while the technical assumptions of their generating i.e. a so called Standard of Digital Forest Map (SLMN) were defined by the Regulation No 74 of 23 August 2001. It has defined in detail the standard of map generating at the level of a forest district and implementation of the GIS. It was modified by the next Regulation No 43 of 18 April 2003. At the present moment 167 forest districts (about 40 %) are furnished with digital forest maps, and other 104 will receive them soon, thus in 2005 almost 63 % of area of Polish State Forests will be managed on the basis of LMN.

A subcompartment (forest stand) is the basic structural entity of the spatial subdivision of Polish State Forests, having under the Information System of State Forests, a unique for whole Poland, primary key called the "forest address". It is a combination coded in form of a string of characters, like: Regional Directorate, Forest District, Working Circle, Forest Range, compartment, and subcompartment (e.g. 17-13-3-13-64-b-00). The basic criteria for separation of the forest survey units are: the need of a different silvicultural treatment and the necessity of securing the proper accuracy of inventory in the case of diversification of taxation characters (i). The subcompartments are formed from the forest survey units assuming the principle that for forest lands they must be at least 0.01 ha in area. In some cases the area must be greater than 0.10 ha (e.g. forest nurseries, timber landings, parkings), or greater than 0.50 ha (tree plantations, cutting areas, clearings).

Remote sensing provide information concerning spatial and (multi-) temporal distribution of forest complex. Combinig the 2D (spatial location XY) and temporal (time factor) data enables the assesment of the status of forest ecosystem and occured changes. The use of aerial photographs in forestry has increased during the last several decades along with propagation of Color Infra Red films, digital photogrammetric stations and facilitations in generating of aerial ortophotomaps or appearance of airborne digital cameras (iii, iv, v, vi). The integration of photogrammetric workouts with other technologies, such as LiDAR (vii),GPS, or GIS (viii) is applied not only in the forest inventory research (ix) but also in forestry practice. Technologies of imaging the earth's surface (EO) yielding the satellite images have been used since long ago in forestry to determine the forest type, forest mixture, and biomass as well (x, xi, xii, xiii, xiv). The revision and updating of forest maps may also be connected with development of object classification (ix) which creates new possibilities in a semi-automatic or fully automatic methods of forest stand mapping based on multi- and hyperspectral airborne and satellite (e.g. IKONOS, QuickBird, Orbview) images as well as aerial photos (xv, xvi, xvii, xviii, xix). Thanks to a continuous progress in technology, the airborne scanners (e.g. AISA, HyMap, CASI, AVIRIS, Daedalus, etc.) with resolution of several dozen or several hundred spectral channels, reach a high ground resolution, and their practical use in forestry ever increases (xx, xxi, xxii). Hyperspectral airborne imagery might be used for detecting and mapping of single tree stress, like insect infestations (xxiii) or fungous diseases (xxiv) and for the health monitoring of large forest areas (xxv) and sustainability as well (xxvi). Also the mapping of the different types of vegetation and soil may be accomplished on the basis of the classification of hyperspectral images (xxvii).

The main purpose of this study was to demonstrate the usefulness of the hyperspectral scanner AISA (Airborne Imaging Spectrometer for Applications; Specim) in the process of revision and updating of the digital forest maps (LMN) generated on the basis of geometrical and attribute databases used in Polish State Forests.

METHODS

Test site

The Niepolomice Forest (southern Poland), a remnant of the great primeval forest lowland (Fig.1), located close to Cracow, was chosen as a test site for this study.

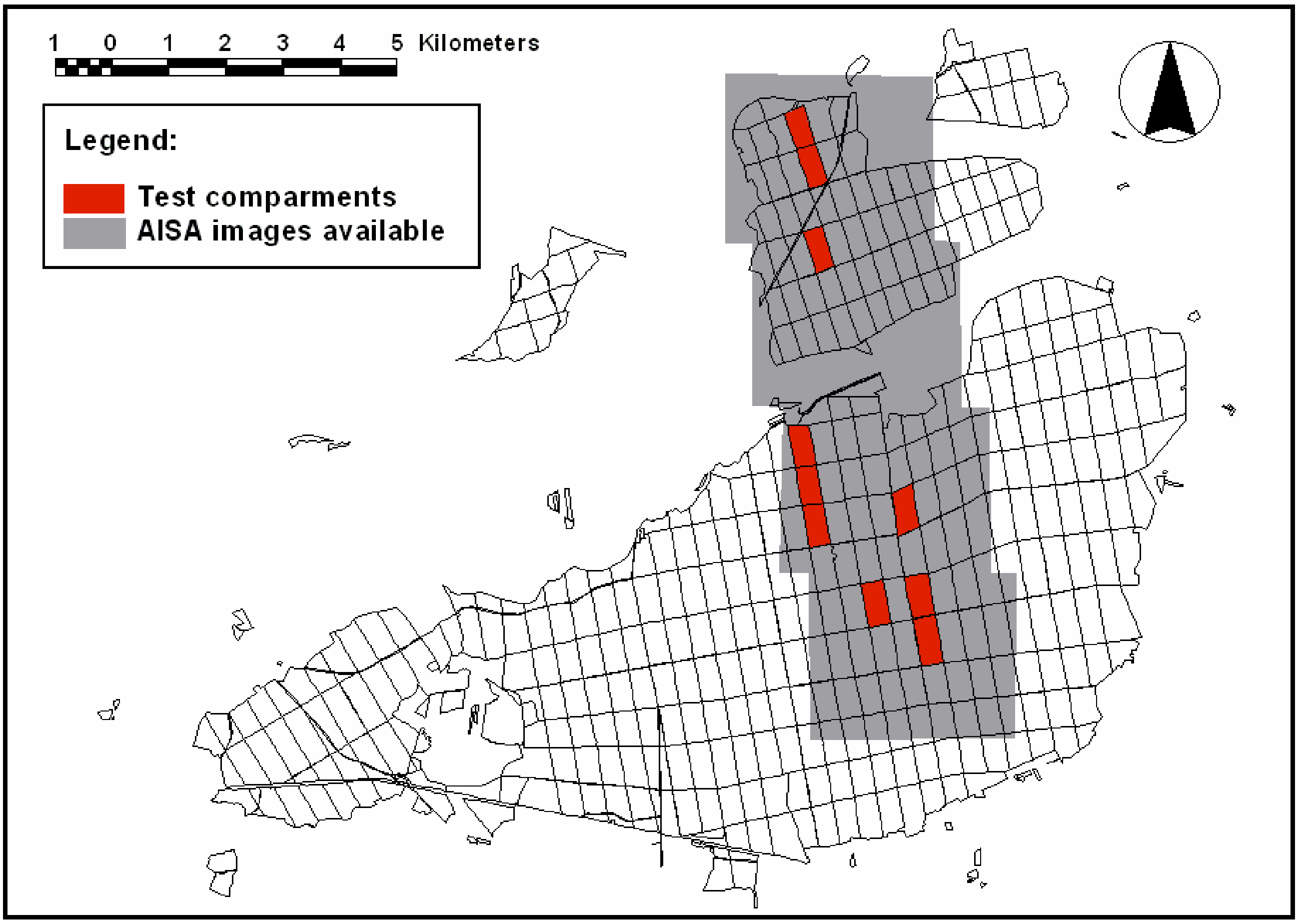


Figure 1: Location of analyzed compartments in the Niepolomice Forest District

The Niepolomice Forest (RDLP Krakow) of 10 512 ha in area, is composed of two main parts. The southern "main complex" (about 8 500 ha) is generally composed of coniferous and mixed forest (Pino-Quercetum) and the northern complex (about 1.850 ha) is dominated by natural deciduous forest stands (Tilio-Carpinetum). The tree species in the Niepolomice Forest, especially in its southern "main complex" has been distinctly changed by man resulting in prevalence of coniferous species introduced to sites proper for broadleaf tree species. The present species composition of the Niepolomice Forest stands is as follows: Scots pine (66 %), oaks (19.3 %), and black alder (10.6 %). Due to the occurrence of mixed stands (Pino-Quercetum) in the Niepolomice Forest, and its compact complex, as well as numerous investigations carried out in the past, this area has been selected as one of the three nodes of the FOREMMS (Forest Environmental Monitoring and Management System 5FP EU IST 1999-2002). One of the main objectives of the FOREMMS project was to create an information system about forests of Europe, working on several levels (L1, L2, and L3). The task of AISA was to supply information to databases of the most detailed level L1 along with information coming from the terrestrial forest inventory.

Field work

The AISA images, originating from flight of the research aircraft SC7 SkyVan (HUT) over the east part of the Niepolomice Forest (Fig. 1) on 13 Aug 2001 within FOREMMS were used in this study. The AISA scanner may register waves of range 430–900 mm divided into maximum 288 channels, 1.6 to 9.4 mm wide. During the flight AISA registered radiation in 32 separated spectral channels of dedicated width fixed in order to correlate the values of reflection with concentration of selected photosynthetic pigments. At flight altitude of 1000 m and speed of 50 m/s the ground resolution of images of 1m x 1m was obtained (xx). The position of the aircraft was determined on the basis of the read-outs of the DGPS (Boening) receiver and the system INS.

To create a developed interpretation key (training areas) and the maximum likelihood classification of AISA images, the area network of FOREMMS monitoring plots was used, and additional training and test areas (ROI) were established using DGPS measurement (xxviii) and applying a GPS Pathfinder PRO XRS (Trimble) receivers and reference station in Cracow (Trimble).

Laboratory work

In utilized GIS analyses and revision of the attribute and geometrical databases, the digital forest map and revelant descriptive base of the Information System of State Forests (created in 2001 as the result of forest inventory), made available by the Niepolomice Forest District (Krakow Regional Directorate) were used. During the work, the ENVI software (maximum likelihood classification) and ER Mapper (georeferencing, ECW compression) were used. Due to large illumination differences during the flight (effect of clouds) the updating of digital forest map was carried out separately for selected test compartments, free from geometrical distortions and situated in the same flight strip. For this purpose 10 forest compartments, of different internal variability (number and shape of subcompartments) numbered: 32, 52, 71, 75, 156, 158, 183, 425, 432, and 461 were selected for this study (Fig. 1). To determine usefulness of AISA images in the process of revision and updating of the digital forest map, two methods were used (Variants I and II) differing in the degree of interference in the existing spatial forest subdivision.

- Variant I – a method of interpretation and screen vectorization of the AISA image. The correction of subcompartment (forest stand) delineation was made only on the basis of observation of AISA images (composition of RGB channels numbered: 25 (790nm), 16 (673nm), and 10 (555nm). No changes of the number of subcompartments was made (no new ones were created), and only the revision and updating of boundaries existing within tested compartments were carried out.
- Variant II – A combined method based on the maximum likelihood classification of the AISA image, and also on the existing attribute SILP database and digital forest maps. In the maximum likelihood classification based on the training areas selected during creation of the interpretation key and establishment of 186 FOREMMS areas, all 32 available spectral channels were used (xxii). In this method the updating or removing of existing subcompartments, and creation of new ones take place. In the case when stands differed slightly in age and other forest taxation characters, the subcompartments were united if classification showed similar results.

Taxation characters

In addition, in the Variant II (a combined method) the possibility of determination by AISA images of selected taxation characters of stands, including the actual production area (understood as the area of a vertical projection of crowns on a horizontal surface) was tested. This area was determined for individual subcompartments in per cent, on the basis of image classification, as the sum of classes making the stands.

The designation of image pixels fulfilling the criteria of forest inventory was tested qualifying them to:

- Gaps – treeless areas in stands older than 20 years, but not designated for final cutting, over 0.02 ha in size.
- Clusters – their volume must be registered in the SILP system, and as in the case of openings and clumps, their location must be defined. However, the Instruction of Forest Management (§ 28 pnt 7) orders in the case of these objects, not forming subcompartments, to measure their contours (shape) directly on the ground or use for this purpose the aerial photographs or satellite images.

Delimiting of the gaps, openings, and clusters was carried out automatically on the result of classification of the AISA image using a logical query to the geometrical database. The selection of the following objects was carried out:

- Gaps – compact fragments over 0.02 ha in area classified as the class „Shadow";
- Openings – compact fragments over 0.02 ha in area classified as the class „Grass", inside a surrounding stand, and
- Clusters – compact fragments over 0.02 ha in area classified as a stand not formed by the dominant tree species in a given subcompartment.

RESULTS

The AISA images supplied by HUT were burdened with errors resulting from technical problems of power supply of the DGPS system, and this caused interruptions in reading of the scanner position (WGS84). Therefore the errors in determination of the position affected the correctness of mosaicking of several dozen flight strips and also the image calibration. Thanks to the additional calibration based on 15 GCP evenly distributed within the entire mosaic, the average geometric accuracy (RMS error) of about 4 meters was attained. To compare the accuracy to the quality of forest map we have to notice that the 1mm of on the analogue forest map (printed) in scale 1:10.000 mean 10 meter in the forest. The taxation description of stands recorded in the database of the Information System of State Forests showed large divergences between the file (record/ Field value) and their actual area (geometry in shape file). For the test compartments this error varied from 3 % to over 14 %. The actual (not a file) area of subcompartments, generated from the shape file, was taken as the reference point for the analysis of the AISA image.

It is very difficult to present the results of analyses carried out in Variants I and II using per cent changes (in the area as well as in the length of spatial subdivision lines). Probably the most correct way would be utilization for this purpose of the method of indexes which are frequently used in the description of changing elements of landscape (e.g. indexes of changes in area of subcompartments, their number, and object shape). The results of testing the respective methods of updating and revision of digital forest maps (Variants I and II) are shown below, using compartment No 183 as an example (Fig. 2).

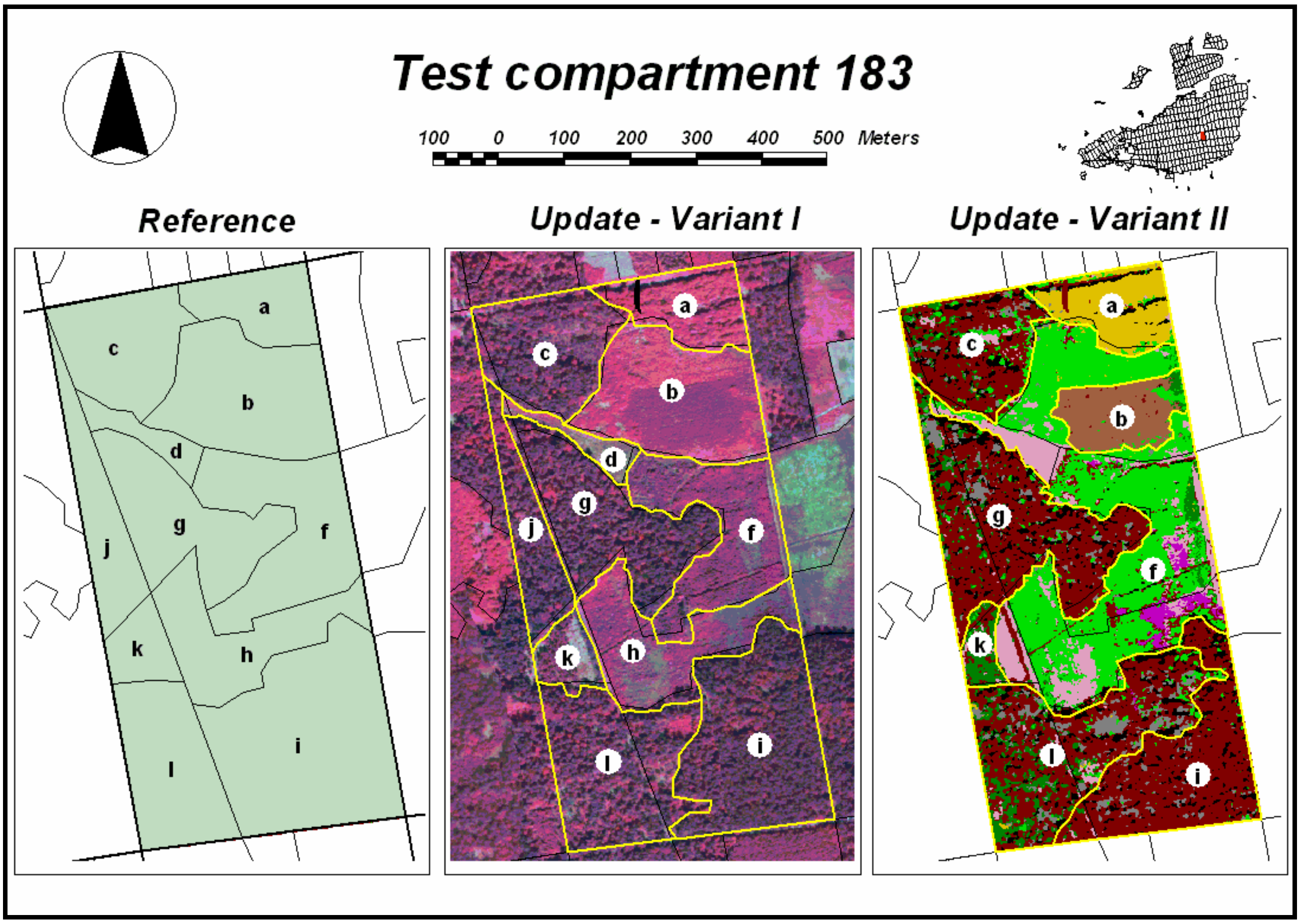


Figure 2: The actual state (reference) and the result of application of Variants I and II of updating for forest compartment No 183.

Using the method of Variant I, on the basis of a visual interpretation of the RGB composition shown on the screen, the correction of subcompartment boundaries was made adjusting it to the actual situation in the compartment. In the compartment No183, corrections concerned all of 11 existing subcompartments. The differences in relation to the existing digital forest map were mainly revealed in the course of boundaries of subcompartments „i" (- 21 %) and „l" (+ 34 %), and also in decreased area of subcompartment „d" (- 24 %) in favour of adjacent subcompartments „g" and „j".

On the basis of the Variant II a new definition of the course of subcompartment boundaries was made using at the same time information from the attribute database of the Information System of State Forests and results of the maximum likelihood classification of the image. The correctness of attributing the pixel classes to the proper object classes for the tested compartment No 183 was 88.5 % on the average. In this compartment for example subcompartments „g" and „j" (almost pure pine stands, 105–110 years old) were joined with each other, as well as the subcompartments „d" and „h" (wet area overgrown with alder of poor reforestation success together with grasses and sedges). At the same time the boundaries of subcompartments: „b" (considerably smaller area actually covered with pine sapling stand), „i" (stand with high percentage of pine), „l" (pine stand with oak and alder admixture), and „k" (alder stand) were considerably altered. The new subdivision only little altered the boundaries of subcompartments: „a" (beech stand) and „c" (pine stand 90 years old) confirming their correct location and description in the existing database of the Information System of State Forests.

The determination of the actual production area for individual subcompartments in compartment No 183 showed the lowest value for subcompartment „f", and this was confirmed by field work. There is a young alder stand of low reforestation success which should be reforested again. While the highest value of production area was found for subcompartment „b" – a very dense pine sapling stand.

Detailed characteristics of changes in subcompartment area in all test compartments, defined in two Variants (I and II) of revision and updating of digital forest maps are shown below (Table 1).

Table 1: Results of revision and updating of digital forest maps on the basis of Variant I and II. The per cent change in relation to existing area subdivision is in parenthesis. The following abbreviations are used: .e. – not exist, del-removed, new – newly created.

Compartment	Subcompartment	Reference [ha]	**Variant I** [ha] ([%])	**Variant II** [ha] ([%])	Compartment	Subcompartment	Reference [ha]	**Variant I** [ha] ([%])	**Variant II** [ha] ([%])
32	a	2,22	1,63 (-27)	0,67 (-70)	**156**	f	10,92	11,11 (+2)	15,11 (+38)
	b	1,00	1,16 (+17)	1,03 (+3)		g	3,37	3,86 (+15)	0 (del)
	c	2,98	2,61 (-13)	1,53 (-49)		h	n.e.	n.e.	1,12 (new)
	d	1,33	1,26 (-5)	1,41 (+6)		i	n.e.	n.e.	1,28 (new)
	f	3,68	4,79 (+30)	7,83 (+113)		j	n.e.	n.e.	0,58 (new)
	g	2,10	1,10 (-48)	1,06 (-49)		k	n.e.	n.e.	1,66 (new)
	h	4,98	6,87 (+38)	5,22 (+5)		l	n.e.	n.e.	0,67 (new)
	i	1,90	2,54 (+34)	0 (del)		m	n.e.	n.e.	0,44 (new)
	j	6,62	4,84 (-27)	7,11 (+8)		n	n.e.	n.e.	1,86 (new)
	k	n.e.	n.e.	0,96 (new)	**158**	a	8,21	10,19 (+24)	8,05 (-2)
52	a	10,49	8,20 (-22)	10,24 (-2)		b	4,36	1,67 (-62)	3,01 (-31)
	b	2,83	3,65 (+29)	4,10 (+45)		c	4,13	4,51 (+9)	3,44 (-17)
	c	0,77	1,00 (+30)	1,04 (+35)		d	13,57	13,9 (+3)	14,23 (+5)
	d	3,02	4,05 (+34)	0 (del)		f	n.e.	n.e.	0,52 (new)
	f	0,56	0,51 (-10)	0,59 (+6)		g	n.e.	n.e.	0,74 (new)
	g	0,11	0,23 (+107)	0 (del)		h	n.e.	n.e.	0,30 (new)
	h	4,27	4,39 (+3)	4,38 (+3)	**183**	a	1,89	2,01 (+7)	2,03 (+8)
	i	1,29	1,04 (-20)	0,59 (-54)		b	4,39	4,41 (+1)	1,78 (-60)
	j	1,19	1,46 (+23)	1,36 (+15)		c	3,04	3,24 (+7)	3,14 (+3)
	k	n.e.	n.e.	0,30 (new)		d	0,79	0,60 (-24)	0 (del)
	l	n.e.	n.e.	1,59 (new)		f	4,13	3,83 (-7)	10,78 (+161)
	m	n.e.	n.e.	0,33 (new)		g	3,64	4,25 (+17)	5,98 (+64)
71	a	2,94	4,53 (+54)	2,92 (-1)		h	3,09	3,34 (+8)	0 (del)
	b	6,66	3,74 (-44)	6,17 (-7)		i	7,07	5,61 (-21)	4,51 (-36)
	c	1,36	1,76 (+30)	0 (del)		j	2,14	1,88 (-12)	0 (del)
	d	0,72	0,93 (+30)	0 (del)		k	1,01	0,89 (-12)	0,64 (-37)
	f	4,03	3,93 (-3)	1,39 (-66)		l	3,35	4,48 (+34)	5,68 (+70)
	g	3,92	4,40 (+12)	1,69 (-57)	**425**	a	11,34	10,45 (-8)	5,31 (-53)
	h	2,57	2,91 (+13)	2,70 (+5)		b	0,43	0,53 (+23)	0 (del)
	i	2,68	2,22 (-17)	1,72 (-36)		c	2,45	2,03 (-17)	1,93 (-21)
	j	4,71	5,15 (+9)	5,36 (+14)		d	0,26	0,57 (+116)	0,52 (+96)
	k	n.e.	n.e.	1,44 (new)		f	0,64	0,56 (-12)	0 (del)
	l	n.e.	n.e.	2,26 (new)		g	1,97	1,51 (-23)	2,98 (+51)
	m	n.e.	n.e.	0,89 (new)		h	3,65	4,75 (+30)	10,50 (+187)
	n	n.e.	n.e.	0,81 (new)		i	4,26	4,61 (+8)	3,77 (-12)

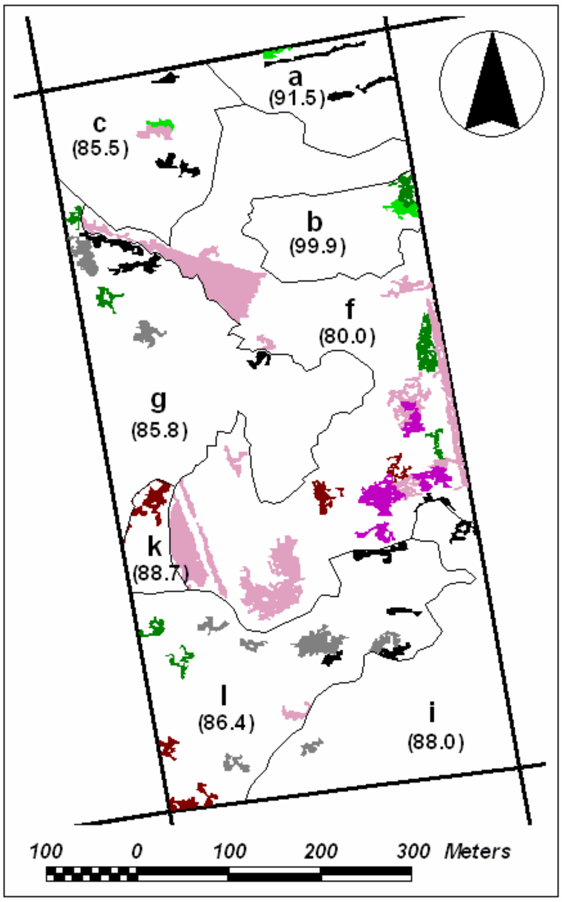
Compartment	Subcompartment	Reference [ha]	Variant I [ha] ([%])	Variant II [ha] ([%])	Compartment	Subcompartment	Reference [ha]	Variant I [ha] ([%])	Variant II [ha] ([%])
	o	n.e.	n.e.	0,89 (new)	**432**	a	3,32	2,80 (-16)	3,33 (+0)
	p	n.e.	n.e.	0,50 (new)		b	5,02	4,33 (-14)	4,25 (-15)
	r	n.e.	n.e.	0,83 (new)		c	1,87	3,01 (+61)	2,85 (+53)
75	a	3,03	2,80 (-8)	2,98 (-2)		d	1,15	0,90 (-21)	0 (del)
	b	4,66	3,56 (-24)	3,24 (-30)		f	12,45	12,78 (+3)	12,53 (+1)
	c	4,37	4,44 (+2)	4,11 (-6)		g	1,45	1,44 (-1)	1,51 (+4)
	d	4,59	4,83 (+5)	5,08 (+11)		h	n.e.	n.e.	0,79 (new)
	f	11,41	12,43 (+9)	12,43 (+9)	**461**	a	6,02	5,88 (-2)	0 (del)
	g	n.e.	n.e.	0,22 (new)		b	13,87	12,32 (-11)	21,74 (+57)
156	a	5,31	5,80 (+9)	4,53 (-15)		c	3,03	4,66 (+54)	0 (del)
	b	3,75	3,03 (-19)	1,29 (-66)		d	1,81	1,99 (+10)	2,20 (+21)
	c	4,17	3,43 (-18)	1,76 (-58)		f	1,29	1,18 (-8)	1,90 (+47)
	d	4,20	4,50 (+7)	1,43 (-66)		g	n.e.	n.e.	0,19 (new)

The application of the Variant II caused revision of existing subcompartments and undertaking of the decision about a new area subdivision. The changes in numbers of compartments are shown below (Table 2).

Table 2: Changes in numbers of compartments according to the new area subdivision (Variant II).

Forest compartment	Number of subcompartments		
	Reference (LMN 2001)	Variant II	
		Updated	New created
32	9	8	1
52	9	7	3
71	9	7	7
75	5	5	1
156	6	5	7
158	4	4	3
183	11	8	0
425	8	6	0
432	6	5	1
461	5	3	1

The maximum likelihood classification of the AISA image permitted to create the classes representing gaps and openings in the stand. Additional clusters of trees (result of classification) were tested from the point of view of fulfilling the conditions defined in the Instruction of Forest Management (i). Also the size of the actual production area of subcompartments was determined using compartment No 183 as an example (Fig. 3).



Selected taxation characters of stands in test compartment 183

	subcompartment							
	a	b	c	f	g	i	k	l
gaps	3		3	1	3	1		4
openings			1	17				1
clusters	1	2	1	4	4	1	1	10

Legend:
- Pine - less than 21 years old
- Pine - more than 100 years old
- Oak - more than 100 years old
- Alder - less than 21 years old
- Alder - between 21 and 100 years old
- Beech - between 21 and 100 years old
- Meadow
- Sedge
- Shadow

Percent of actual production area indicated in paranthesis

Figure 3: Selected taxation characters of stands in the test compartment 183.

CONCLUSIONS

Frequently forest maps used in Polish State Forests are burdened with errors. The causes of such a situation should be looked for in the process of their generation on the basis of archival analog maps. The quality of these maps has not been verified until now on the basis of aerial photographs, ortophotomaps, and an image of the airborne scanner or the DGPS measurement. The annex No 8 to the standard of a digital forest map (xxix) stresses that „the basis of application of the digital forest map as a GIS element is its actuality...” and that the updating of a geometric base must be carried out parallel to changes made in the attribute base of the Information System of State Forests. A lack of the unmistakable definition of the term „regularity” causes problems for forest district employees who must make updating by themselves. Special programs for these tasks have been worked out, such as „UPDATER” or „Digital forest map check-up” (xxx), checking up the quality of the digital forest maps obtained from their executors.

This study confirmed that the ground resolution of AISA pixel (1 x 1 m) is fully sufficient for updating and revision of boundaries of area subdivision. It is possible to distinguish on the image the homogeneous fragments (stand/compartment) as well as single crowns of trees in older age classes (especially of broadleaf trees). Using the combined method (Variant II) for revision and updating of stand boundaries makes the elimination of errors in forest maps (geometric) and records in attribute databases possible.

In order to fully utilize the potential of the high-resolution hyperspectral AISA images a proper carrying out of the flight (light conditions uniform for the entire area) as well as of the process of mosaicking and georeferencing the image (measurement GPS and INS) must be secured. The errors due to wrong mosaicking of the image considerably limit the usefulness of AISA image in maximum likelihood classification (xxii).

High-resolution AISA images are a very rich source of information about the forest ecosystem. Their utilization makes the correction and current updating of existing area subdivision possible. The results of this study indicated that using information contained in only three properly chosen spectral channels (Variant I of updating) gives the user the possibility of correction of the existing subdivision in agreement with actual state. The maximum likelihood classification of the AISA image, applied in Variant II, permits to take into account all of the information stored in 32 spectral channels during updating of digital forest maps.

The result of updating based on image classification is undoubtedly affected by a carefully defined training areas (ROI) chosen on the basis of the interpretation key, as well as the image preprocessing, i.e. their proper georeferencing, and finally mosaicking. The maximum likelihood classification AISA carried out showed a high accuracy in identification of species of coniferous and broadleaf trees and other non-forest objects. It is also the basis for an automatic distinguishing of additional elements of forest taxation of defined descriptive attributes (e.g. species, age) and spatial ones (e.g. area, geographic coordinates) such as gaps and openings by SQL queries to the geometic database created within the classification (conversion of raster to vector).

The Instruction of Forest Management (i) allows the obtaining information about geometry of objects on the basis of aerial photographs or by VHR satellite data, and this opens the possibility of utilization of airborne hyperspectral scanners in forest inventory. Other legal basis, i.e. Annex No 2 to the standard of digital forest maps (xxix) confirms this possibility since it states that „ admissible are (...) satellite images of ground pixel resolution not greater than 6 x 6 m...." (Pnt 2.2.2.2).

At the present time the aerial ortophotomaps, also covering forest areas, are made for the system IACS-LPIS using EU founds. But they mostly use B&W aerial photos in scale 1:13.000 (xxxi), and therefore they are not too useful for forest inventory. A VHR IKONOS satellite images, characterized by the size of the ground pixel close to that of the AISA scanner (1 x 1 m PAN) have been made for the frontier areas of Poland. The IKONOS, however, registers only 4 spectral channels, which means smaller possibilities in classification and interpretation in comparison with AISA images. Therefore the AISA images would successfully serve for a cyclic updating of digital forest maps (geometry) and updating the attribute databases. It is of a particular importance in situation when the State Forest Holding charters every year many aircrafts or helicopters to inspect forest fire hazard. The hyperspectral scanner AISA could therefore be easily implemented as a forest monitoring tool securing high quality information about the forest ecosystem at relatively small financial expenditures as this has been suggested in several financial projects of the Polish State Forests (xxxii).

The development of technology of object oriented classification and utilization of rich information stored in many spectral channels creates a hope for the prompt utilization of semi- or fully automatic methods of image processing (xxxiii) for updating of databases (geometric and attribute) used in the Polish State Forest.

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