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INTERPRETABILITY OF SPOT DATA FOR GENERAL MAPPING

E. Ahokas, J. Jaakkola and P. Sotkas

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complexes et irréguliers rencontrés dans le Sud de la Finlande.

Au total neuf interprétations complètes ont été effectuées par cinq instituts; les résultats de ces interprétations ont été étudiés par le centre pilote (en l'occurence l'Institut géodésique de Finlande) qui a également tiré les conclusions de cet essaie.

Il apparait que l'imagerie de SPOT ne peut fournir à elle seule toutes les informations sur l'occupation du sol, nécessaire à l'établissement d'une carte topographique. On a pu dans cette essaie identifier trois classes d'usage du sol (eau, terres agricoles, forêts) avec une précision caractérisée par un taux d'omissions et d'artefacts inférieur à 10 %. On peut aussi considérer que les zones bâties et les carrières ont été, sous certaines conditions, suffisamment bien identifiées. Les éléments linéaires sont apparus nettement visibles dans les scènes à pixel 10 m. C'est ainsi que toutes les routes de largeur supérieure à 5 m et environ 90 % de celles de largeur inférieure ont pu être détectées par des méthodes purement visuelles. Mais on n'a pas pu établir avec précision la classification de ces routes en se basant uniquement sur l'interprétation des images.

Lorsque l'on se limite à un petit nombre de thèmes surfaciques d'occupation du sol, il n'y a pas de difference sensible entre l'emploi du couple stéréoscopique panchromatique et les données multibandes. Pour les thèmes linéaires en revanche, la résolution 10 m est apparue nettement supérieure.

Les interprétations visuelles ont fourni en général de meilleurs résultats que les méthodes de classification automatique des pixels. Toutefois la formation et l'expérience des photo-interprètes ont une grande influence sur les résultats et l'on a constaté de grandes disparités à cet égard. De sorte que les résultats des interprétations visuelles ne constituent pas seulement des indicateurs sur la qualité de l'imagerie mais aussi sur la qualification de l'interprète.

On a obtenu la précision la plus grande au total en recourant à la conjugaison d'une interprétation visuelle et d'une classification automatique.

Zusammenfassung

Die Studie wurde erarbeitet, um die Interpretationsmöglichkeiten in SPOT-Aufnahmen hinsichtlich physikalischer und künslicher Objekte, die topographische Karten wiedergeben, zu untersuchen.

Vier unterschiedliche Szenen, zwei multispectrale und ein panchromatisches Stereopaar, wurden nach verschiedenen visuellen und automatischen Methoden interpretiert. Das Testgebiet stellt eine typische bewegte und vielfältige Landschaft im Süden Finnlands dar.

Fünf Institute lieferten 9 vollständige Interpretationen. Das Pilot Centre (das Finnische Geodätische Institut) analysierte die Ergebnisse und faßte zusammen.

SPOT-Bilder enthalten nicht alle Bodennutzungen, die in topographischen Karten dargestellt werden. Im allgemeinen lassen sich 3 Klassen der Bodennutzung (Wasser, landwirtschaftliche Flächen und Wald) genau interpretieren, die Fehlerrate liegt dann bei 10 %. Unter gewissen Bedingungen können auch bebaute Gebiete und Flächen, wo Boden entnommen wird, ziemlich gut interpretiert werden. Linienförmige Objekte werden gut sichtbar auf den Szenen mit 10 m Auflösung. Alle Straßen, die breiter als 5 m sind, und 90 % der schmaleren Straßen konnten mit visuellen Methoden interpretiert werden. Es war unmöglich, Straßen genau zu klassifizieren, wenn man nur die Bildinterpretation benutzt.

Wenn die Anzahl der zu unterscheidenden Bodennutzungen klein ist, gibt es keine wesentlichen Unterschiede zwischen dem panchromatischen Stereopaar und den multispectralen Daten hinsichtlich der Interpretationsmöglichkeit. Bezogen auf die linearen Objekte sind die Daten mit einer 10 m-Auflösung klar überlegen.

Im allgemeinen gab die visuelle Interpretation bessere Ergebnisse als die automatischen Klassifikationsmethoden auf Pixel-Basis. Die Ausbildung und die Erfahrung der Interpreter führte jedoch zu wesentlichen Unterschieden in den Ergebnissen. Deshalb spiegeln die visuellen Interpretationsergebnisse nicht nur die Qualität der Szenen wieder, sondern auch die Fähigkeiten der Interpreter. Eine Kombination von visueller Interpretation und automatischer Klassifizierung führte zu dem besten Gesamtergebnis.

2 Test area and material

2.1 Test area

In this study two neighbouring test areas had to be used because the overlap of the stereopair did not match with the test area used earlier for interpreting XS-imagery. However, these test areas covered partly the same area.

The test areas are located in Southern Finland near the city of Lohja. The first is about 20 x 30 km^2 and the second is about 20 x 15 km^2 (appendices 1 and 2). The land cover of both areas is varied and includes agricultural lands, different types of forest, lakes , pools, rivers, wetlands, quarries, built up areas, and several road classes. The feature size of land cover categories is very changeable, and many features are very small (appendix 3). The topography of the region contains small variations ($z = 30..153$ m).

2.2 Material used for interpretations

2.2.1 Satellite data

Four SPOT scenes were investigated in this study (see table 1). All the requested imagery was not acquired in the same year and the overlap of the panchromatic stereo pair did not cover the wanted area.

On the test area of the first XS-scene (Ref.no. 1) there were two radiometrically different along-track belts (see figure 1). The width of these belts was 15 km, thus they covered areas registered by different CCD linear arrays of the detector in HRV 2. The effect of these bipartition upon the interpretations was probably minor, because the other factors, like changes in the appearance of a class between different parts of the test area, were more prominent, and the small systematic shift in grey values due

Scene Ref.no	Mode	Grid Reference System (GRS)	Date	Off-nadir view	Quality
1	XS	70-226	860614	vertical	medium
2	XS	70-226	870623	10.0° E	medium
3	Pan	70-226	870623	10.0° E	good
4	Pan	70-226	870720	9.7° W	good

Table 1: *Image acquisition. The scenes 3 and 4 form a stereopair.*

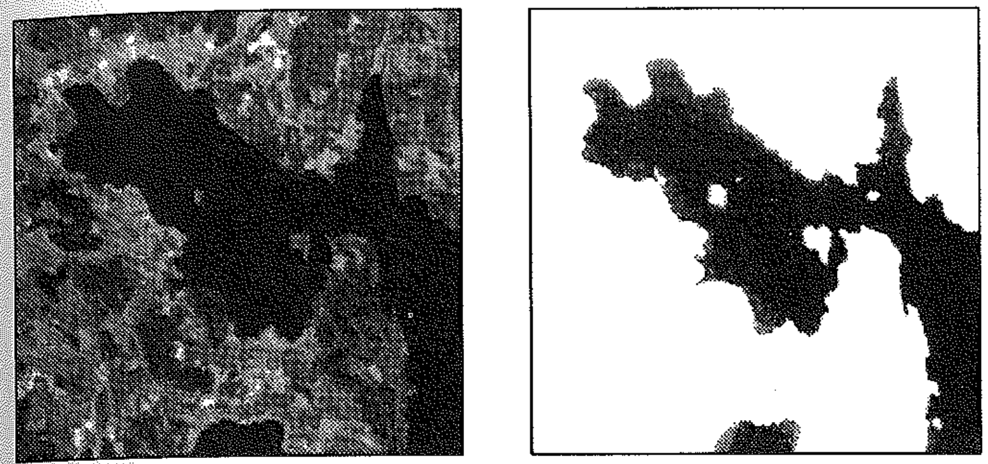


Figure 1: *Subscene of SPOT XS 860614 CH 3 (5 km x 5 km). The area covers two belts registered by different CCD linear arrays of the detector in HRV 2. On the left: the subscene is linear contrast stretched between image grey values of 0 and 120 (DN). On the right: the output image is linear contrast stretched between image grey values of 8 and 15. The limit between the belts is clearly visible in the middle part of this subscene where striping appears only in the eastern part of the lake.*

to the bipartition disappeared in the general variation of the class (appendix 4).

The XS-image data of 1987 (Ref.no. 2) contained striping. The along-track striping was less disturbing in the other images. Otherwise the quality of the image data was good. The cloud cover in the Pan-image no. 4 slightly disturbed the interpretation.

The stereoscopic effect was poor on the panchromatic stereo pair. This is due to the low relief of the test area and the base-height ratio which was small (0.39).

The pilot centre delivered the imagery data according to the orders of the participants (see table 2). The original digital data had been corrected, when needed, to the level 1B and processed by the National Board of Survey of Finland. The digital data was either geometrically corrected by the pilot centre or unrectified. The geometric correction was made by using the nearest neighbour resampling method. If the image was delivered unrectified it was accompanied by a map of the ground control points and a list of co-ordinates.

The false colour composites (FCC) were delivered in films or in paper prints. When the interpretability of the multispectral image was studied, the combination of bands was blue (channel 1), green (channel 2) and red (channel 3). The XS/P-combination image was made by the Finnish Geodetic Institute using the IHS-transformation process. In this process the panchromatic image was first rectified to the map coordinate system.

Participant	Scene(s) Ref.No.	Level	Contrast Manipulation	Product(s)	Training material
GL1	1	2	none	CCT, FCC-paper print	Basic Map, B/W air photo
GL2	2+3	2	stretching	FCC-paper print	Basic Map, IR air photo
GL3	3+4	1A	stretching	B/W-films	Basic Map, IR air photo
IFAG	1	2	none	CCT, FCC-paper print	Basic Map, B/W air photo
IGN1	1	1B	stretching	FCC-paper print, B/W films	Basic Map
IGN2	3+4	2	stretching	B/W paper prints	Basic Map, IR air photo
LMV1	1	1B	none	CCT, FCC-film	Basic Map, B/W air photo
LMV2	2+3	2	none	CCT	Basic Map, IR air photo
SKV	3	2	none	CCT	Basic Map, IR air photo

Table 2: *Material delivered to the participants.*
GL = Geodeettinen Laitos (Finnish Geodetic Institute)
IFAG = Insitut für Angewandte Geodäsie
IGN = Institut Géographique National
LMV = Lantmäteriverket (National Land Survey of Sweden)
SKV = Statens Kartverk (Norwegian Mapping Authority)

MATERIAL	PHASE 1 (1986)	PHASE 2 (1987)
Topogaphical map 1:20 000 (Basic Map 2041 05)	x	
Topographical map 1:20 000 (Basic Map 2023 12)		x
Aerial photograph 1:20 000 (orig. 1:60 000)	x	
Colour infrared photograph 1:31 000		x
Forest stands map 1: 20 000 (from a small area)	x	
Digital elevation model	x	

Table 3: *Auxiliary material available for participants.*

Then the XS-image was rectified to the panchromatic image, and the pixel size was changed to 10x10 m^2. In the IHS-transformation, the XS-data was transformed from RGB-space (red, green, blue) into IHS-space (intensity, hue, saturation). The intensity component was substituted by the panchromatic image and ,finally, the merged image was transformed back into RGB-space.

The black and white photographs were delivered in film or paper prints. The films were enlarged to the scale 1:400000 (for analytical stereoplotter) or 1:200000, and the paper prints to the scale 1:50000.

The contrast stretching and RGB-IHS-RGB colour space transformation were the only image enhancement techniques used before delivering the photographic products. The participants who ordered digital imagery could use other techniques when they considered it useful (see chapter 4).

2.2.2 Auxiliary data

For delineating training areas and defining interpretation keys, auxiliary data was delivered to the participants. The main training data consisted of topographical maps of 1:20000 (Basic Maps), a panchromatic aerial photograph of 1:60000 enlarged to 1:20000 and a color infrared aerial photograph about 1:31000 (see table 3).

The digital elevation model was available for the first test area, but it was not used in any interpretation. A forest stand map from the small area was available for the automatic classifications during the first phase of the experiment as well.

The ordered material was delivered with interpretation instructions (appendices 5 and 6).

2.2.3 Equipment

Different hardware and software were used by the participants for interpreting the SPOT scenes (see chapter 4).

2.3 Material used for evaluating interpretation results

2.3.1 Ground truth data

Three reference areas were selected for testing the accuracies of the interpretations and identifying errors (appendix 2). Together they covered an area of 125 km^2. The selection was based on a visual estimation of representativeness of these areas. The availability of reliable ground truth data had effect on the choice, too. An approximative quality assessment could be made by comparing the areas of the interpreted classes on the reference areas with the areas of the whole test area. Histograms of the satellite data (total or by class) could also be computed on the reference areas and on the total test area for comparing grey value distributions (appendix 4).

The data of the reference areas were collected from Basic Maps, maps for forest management, small scale aerial photographs, and medium scale colour infrared aerial photographs.

The Basic Map field and water masks were digitized by Scitex scanner. For the 20 m resolution data, the scanning was made using a 1:50000 mask and for the 10 m resolution data a 1:20000 mask. Other Basic Map elements which were used in the reference data were collected manually from the Basic maps on plastic sheet 1:10000 and then scanned by Scitex scanner.

The maps for forest management (1: 10000) are mostly based on the interpretation of large scale aerial photograps and on field evaluations in 1980, 1985, 1986, 1987. They contain exact information about the vegetation of the sampling areas.

The black and white photographs had been taken 4 days before the registration of the scene no 1. Their original scale was 1 : 60000 and they were enlarged to 1 : 20000. The

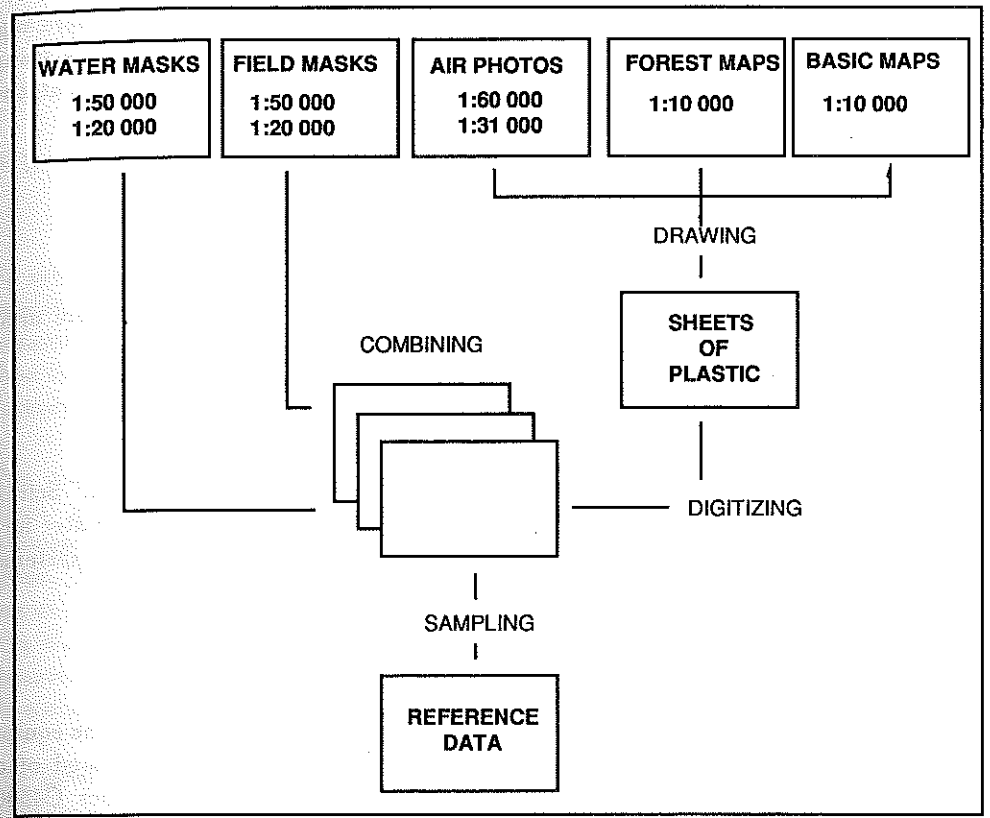


Figure 2: *Reference data collecting and creation of the ground truth images in raster format for testing accuracies of interpreted areal features.*

colour infrared photographs had been taken on 5 July, 1987. Their scale was 1:31000. The quality of all these photographs was good.

Features corresponding to ground truth data were drawn on sheets of plastic and digitized by Scitex scanner. Then this data was transformed into the raster format used in the interpretations (pixelsize 20 m x 20 m or 10 m x 10 m) (see figure 2).

The resolution had effect on the appearance of rivers and brooks in the reference data. When the pixelsize 20 m x 20 m was used only very large rivers were transferred from the mask to the ground truth image. On the contrary, in the reference data with pixelsize 10 m x 10 m, even small rivers and brooks were registered. The pixelsize influenced the shape of the features as well. These effects of the pixelsize were eliminated by the convolution of the ground truth images (see chapter 3.1).

To evaluate the interpretations of roads, the digital road networks were used as reference data. The sheets of the Basic Maps 2041 1 (1 : 50000) and 2023 12 (1:20000)

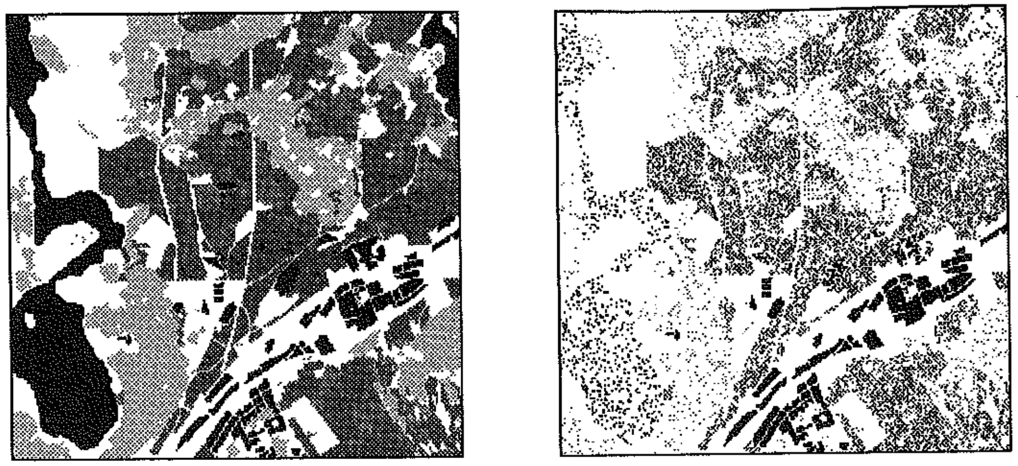


Figure 3: *Part of reference (5 km x 5 km) data before (in the left) and after (in the right) area weighted sampling. The sampling was made by reducing pixels in order that the proportional areas of the land cover classes in the reference data matched with their actual areas in the field.*

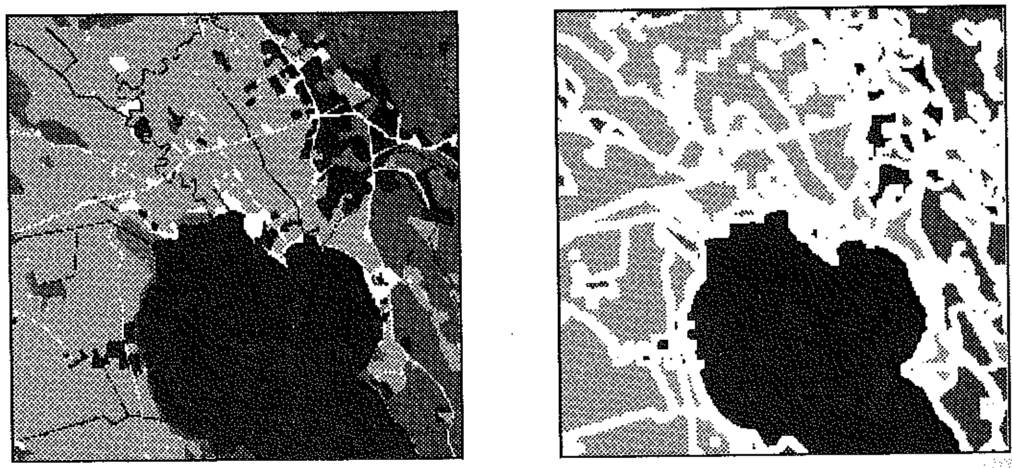


Figure 4: *Part of reference data (5 km x 5 km) before (in the left) and after (in the right) convolution. The boundary pixels of features were eliminated using 5 x 5 kernel (pixelsize 10 x 10 m^2).*

3.2 Accuracy estimation methods

The categories identified for the control pixels were cross tabulated in a contingency table, called an error matrix. An error matrix shows the number of points correctly and incorrectly interpreted. Commission errors (erroneously including a point into a class) and omission errors (erroneously excluding a point from a class) can be identified, too. From this table different measures of classification accuracies were obtained.

For estimating the correctness of interpretations, coefficients developed by Helldén (1980) and Cohen (Bishop et al. 1975) were calculated as follows:

where

x_{ii} = correctly interpreted pixels for class i

x_{ij} = test pixels in class j interpreted for class i

x_{i+} = total number of pixels interpreted for class i

x_{+i} = total number of sampled test pixels in class i

n = total number of sampled test pixels

r = total number of interpreted classes

1. Interpretation accuracy:

$$IA = \frac{x_{ii}}{x_{+i}} 100\%$$

denotes the probability that a randomly chosen pixel of a specific class in the field has a correspondence of the same class in the same position on the interpretation.

2. Object accuracy:

$$OA = \frac{x_{ii}}{x_{i+}} 100\%$$

denotes the probability that a randomly chosen pixel of a specific class on the interpretation has a correspondence of the same class in the same position in the field.

3. Mean accuracy:

$$MA = \frac{2x_{ii}}{x_{+i} + x_{i+}} 100\%$$

denotes the probability that a randomly chosen pixel of a specific class on the interpretation has a correspondence of the same class in the same position in the field and that a randomly chosen pixel in the field of the same class has a correspondence of the same class and in the same position on the interpretation.

4. Total accuracy:

$$TA = \sum_{i=1}^{r} \frac{x_{ii}}{n} 100\%$$

denotes the probability that a randomly chosen pixel on the interpretation has a correspondence of the same class and in the same position in the field and that a randomly chosen pixel in the field has a correspondence of the same class and in the same position on the interpretation (in some cases feature boundary pixels excluded). This estimate does not include linear features.

5. Kappa coefficients:

where

$$\theta_1 = \sum_{i=1}^{r} \frac{x_{ii}}{n}$$

$$\theta_2 = \frac{x_{i+}x_{+i}}{n^2}$$

$$\theta_3 = \sum_{i=1}^{r} \frac{x_{ii}x_{i+} + x_{+i}}{n^2}$$

$$\theta_4 = \sum_{\substack{i=1 \\ j=1}}^{r} x_{ij} \frac{(x_{j+} + x_{+i})}{n^3}$$

Kappa of total interpretation

$$\kappa = \frac{n \sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} x_{i+}x_{+i}}{n^2 - \sum_{i=1}^{r} x_{i+}x_{+i}}$$

Approximative large sample variance of Kappa

$$\sigma_{\infty}^2 = \frac{1}{n} \left[\frac{\theta_1(1-\theta_1)}{(1-\theta_2)^2} + \frac{2(1-\theta_1)(2\theta_1\theta_2 - \theta_3)}{(1-\theta_2)_2} + \frac{(1-\theta_1)^2(\theta_4 - 4\theta_2)^2}{(1-\theta_2)^4} \right]$$

Kappa of individual category

$$\kappa_i = \frac{p_{ii} - p_{i+}p_{+i}}{p_{i+} - p_{i+}p_{+i}}$$

Approximative variance of Kappa of individual class

$$\sigma_{\infty}^2(\kappa_i) = \frac{1}{n} \frac{p_{i+} - p_{ii}}{p_{i+}^3(1-p_{+i})^3} ((p_{+i} - p - ii)(p_{i+}p_{+i} - p_{ii}) + p_{ii}(1 - p_{i+} - p_{+i} + p_{ii}))$$

where

$$p_{ii} = \frac{x_{ii}}{n}$$

$$p_{i+} = \frac{x_{i+}}{n}$$

$$p_{+i} = \frac{x_{+i}}{n}$$

Kappa is a coefficient of agreement for nominal scales which measures the relationship of beyond chance agreement to expected agreement. K = 0 when obtained agreement equals chance agreement. Positive values of Kappa occur from greater than chance agreement while negative values are from less than chance agreement. This coefficient uses all cells in the error matrix (not just diagonal elements) and thus information resulting errors by commission and by omission has its effect on values of Kappa. This coefficient can also be used to construct a hypothesis test for significant difference between two independent error matrices.

In this study a Kappa value was calculated for each matrix and for each individual class. The test of significance between two independent Kappas was calculated as follows:

$$Z = \frac{\kappa_1 - \kappa_2}{\sqrt{\sigma_2(\kappa_1) + \sigma_2(\kappa_2)}}$$

where Z is the standard normal deviate. If Z exceeds 1.96 then the difference is significant at 95 percent probability level. This test is possible because the large sample asymptotic distribution of Kappa is normal.

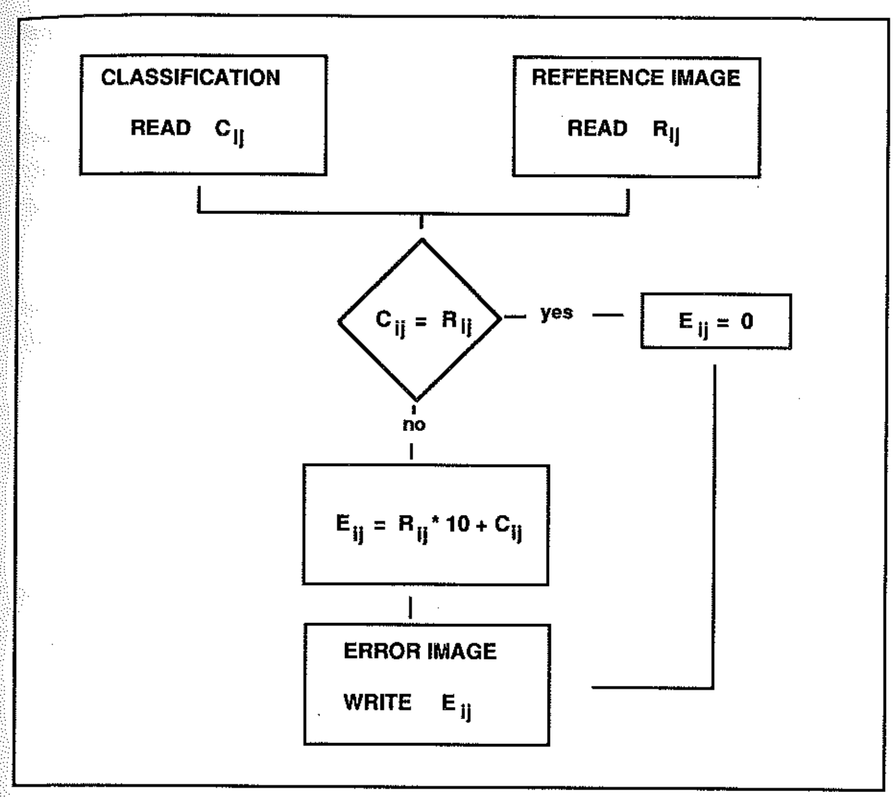
6. Accuracies of line features

Because the interpretation accuracy of the roads could not be evaluated with the methods described above the lengths of all interpreted roads were digitized class by class. Then these were compared with the digitized road network of the maps, and the percentage of correctly interpreted roads was calculated for each class, as well as the commission and the omission of this class.

3.2.1 Error identification and analysis

The spatial error analysis was based on the location of all erroneously classified pixels on the reference areas and the identification of these pixels. Locating and identifying was realized by creating an error image where every erroneously interpreted pixel was coded according to the confused classes.

The error image was computed with a ground truth image and an interpretation as follows. First, the interpreted classes were coded to correspond with the reference classes. Then the images were compared pixel by pixel. All pixels which had been



C_{ij} = classified pixel in position ij $0 < C_{ij} < 10$

R_{ij} = pixel in reference dta in position ij $0 < R_{ij} < 10$

E_{ij} = pixel in error image in position ij

Figure 5: *Computation of error image.*

interpreted correctly got a zero value on the error image. Other pixels were coded so that each confusion combination had its own value (see figure 5).

With the error image, the areas of mis-classification could be printed out. For each class spatial omission and commission with another class could be displayed separately. Thus different types of errors could be identified visually comparing the error image with different field data sources.

When the statistical estimates quantified errors of the interpretations, this method qualified them. It was helpful for identifying mis-classification due to difficult sub-classes, mixed pixels, feature boundaries, or geometric distortions.

3.2.2 Analysis of efficiency

The efficiency of different methods was analyzed by estimating the total time consumed by the work. Man hours and computer time were calculated.

4 Interpretations

Different manual and automatic interpretation methods were used to interpret land use categories. The imagery data was preprocessed by the pilot centre as well as by the authors of interpretations. When necessary the Finnish Geodetic Institute transformed the results of interpretations into digital form using Scitex scanner, an image processing program (DISIMP), and a digitization module of the FINGIS program.

The choice of the classification and the size of the smallest interpreted feature were free.

4.1 Finnish Geodetic Institute

The Finnish Geodetic Institute (GL) interpreted, working together with the National Board of Survey, the XS-image, the panchromatic stereopair, and the P-XS combination image. The first interpretation was automatic and the others were manual. The scheme of the interpretation methods and processes were as follows.

4.1.1 XS-data (GL1)

- scheme of process:
  1. CLASSIFICATION USING PARALLELEPIPED CLASSIFIER AND CHANNEL 3:
     - waters
  2. MASKING THE XS-IMAGE BY THE INTERPRETED CLASS
  3. CLASSIFICATION USING PARALLELEPIPED CLASSIFIER AND ALL 3 CHANNELS:
     - deciduous forest, part of fields
  4. MASKING
  5. CLASSIFICATION USING MINIMUM ERROR CLASSIFIER
     - rest of the fields
  6. MASKING
  7. CLASSIFICATION USING MAXIMUM LIKELIHOOD CLASSIFIER
     - rest of classes
  8. POSTPROCESSING
     - filtering using 3x3 mode filter

The equipment used consisted of a VAX 11/750 host computer, COMTAL VISION ONE/20 image processor, OPTRONICS C4500 film recorder/writer, and DISIMP (module SLIP) remote sensing software.

A total of 7 weeks was spent on training, classification, and postprocessing, which made about 28 minutes per km^2. The computer time used for the whole process was about 14 CPU hours (1,4 min per km^2).

4.1.2 Panchromatic stereo pair (GL2)

This interpretation was realized using KERN DSR-1 analytical stereoplotter, HOUSTON DMP drum plotter (checking interpreted features), SPOT-software for orientating the stereopair, and MAPS 200 mapping software for measuring feature contourline coordinates and plotting the interpretation.

- The interpretation process was as follows:

  1. SETTING UP A STEREO MODEL
     - ground control points gathering
     - preparation of the SPOT data
     - inner and exterior orientation

  2. TRAINING STAGE
     - definition of interpretation keys on the training area
     - choosing the classes

  3. INTERPRETATION
     - by area 5 km x 5 km
     - interpretation feature by feature, except forest class which was the background - co-ordinates of feature contours were registered automatically in digital vector format during the process

  4. POSTPROCESSING
     - transformation of interpretation results into FINGIS format
     - editing the data using FINGIS software
     - vector-raster transformation using SCITEX drum scanner

A total of 2 weeks was spent on the whole interpretation process which made 31,8 min per km^2.

4.1.3 P+XS data (GL3)

In this interpretation a paper print 1:50000 was used. The classification was drawn on 2 separate sheets of plastic drawing material.

In the working process, interpretation keys had been selected on the training area at first. Then the interpretation of the rest of the image had been made class by class. Recognized but not classified patterns had been classified as unknown and the background had been classified as forest.

The interpretation only took about 10 minutes per km^2 included training, interpretation, and drawing.

The quality of this interpretation was poor, thus it could be used only partly when drawing conclusions and considering the interpretability of this type of imagery.

4.2 Institut für Angewandte Geodäsie

The Institut für Angewandte Geodäsie (IFAG) interpreted the XS-image during the first stage of the study. They had performed the digital interpretation method using a new discrimination algorithm developed by the institute itself. The data were geometrically rectified onto the map projection by the pilot centre before the interpretation.

- The whole process contained many stages and the scheme of the interpretation method was as follows:

  1. DATA PREPROCESSING
     a. Standardization with preset mean and variance

     b. Principal Component Transformation
     - information compaction from 3 to 2 significant channels
     - decorrelation of data in the resultant channels
     - reduction of striping caused by faulty sensors

  2. CLUSTER ANALYSIS
     - two dimensional histogram for determining clusters

  3. SELECTION OF TRAINING AREAS
     - using panchromatic airphoto and basic map
     - homogeneity criterion

  4. COMPUTING SEPARATING FUNCTION BETWEEN OVERLAPPING CLUSTERS
     - Maximum Likelihood Method

  5. CLASSIFICATION

  6. CATEGORIZATION OF INDIVIDUAL CLUSTERS IN GROUPS AND ASSIGNMENT OF THE CLUSTER ELEMENTS TO THE MOST LIKELY CLASS
     - Maximum Likelihood Method

  7. NAMING CLASSIFICATION RESULT AFTER LAND USE CLASSES

Classification was conducted by means of the DIPIX digital image processing system and the classification results output was generated on a SCITEX raster plotter. The software for standardization, main component transformation and classification was developed and implemented by IFAG in Fortran for the VAX 11/750 computer.

The interactive work of this classification took 5 weeks and the rest out of the 9 weeks of personal resources used for the whole process contained preprocessing of data, final classification and output results. Man hours spent on this interpretation was about 36 minutes and CPU 0.4 minutes per km^2.

4.3 Institut Géographique National

The Institut Géographique National used a visual method when interpreting both the multispectral image and panchromatic stereopair (IGN1 and IGN2). In these interpretations only the material sent by the pilot centre had been used . The classification was drawn on 2 separate sheets of plastic drawing material (1:50 000). The visual interpretation of the two stages could not be realized by the same person.

The main working process in these two interpretations was the same: At first, the themes had been identified on the Basic Map (and in the second work also on the aerial photograph). Then these themes had been localized on the SPOT print. After comparing the print with the training material, the interpreted classes were chosen and the extrapolation was made on the whole test area.

The basic characteristics of interpretation were tone (hue), texture, shape, site, and association.

The first interpretation took in total 232 and the second 231 hours, which made about 23 and 46 minutes per km^2, respectively.

4.4 Lantmäteriverket

The National Land Survey of Sweden has interpreted both multispectral (LMV1) and panchromatic/multispectral images (LMV2) using a combination of visual and automated interpretation methods. The method of processing was mainly the same in both experiments. Only the preprocessing of images and the manual interpretation varied using different types of imagery.

In the first interpretation the XS-image had been geometrically rectified and edge enhanced (Laplace 3x3 filter). The result had been plotted with a raster plotter in scale 1:50000. The photographic image has also been enlarged to the same scale. The paper and the film copies were then used for visual interpretation of cultivated areas. The results were scanned. In the digital, edge enhanced image roads, streets, built-up areas, railway lines, power lines, and an airfield were visually interpreted. Finally, an automated classification was done using the maximum likelihood classifier. Objects which had previously been visually interpreted were masked.

In the second interpretation, a combination of geometrically rectified panchromatic and multispectral images was used. The merger was accomplished by replacing channel 2 with P-data. Before doing so, the P-image was edge enhanced with a 3x3 Laplace filter. The manual interpretation was done on the screen of an image processor. The automated interpretation was done using the XS channels in a maximum-likelihood classification.

- The scheme of the whole interpretation process in both works was as follows:

1. DATA PREPROCESSING
   - Geometric rectification, edge enhancement
2. MANUAL INTERPRETATION
   - Fields, built-up areas, roads and other line elements
3. MASKING THE DIGITAL IMAGE WITH MANUALLY INTERPRETED CLASSES
4. MAXIMUM LIKELIHOOD CLASSIFICATION
5. DATA POSTPROCESSING
   - Merger of different interpretations, filtering with a 3x3 filter

The equipment used in these experiments was a TERAGON image processing system and a TERAGON flat bed scanner connected to VAX 750 computer, a CALCOMP electrostatic plotter and software developed at the National Land Survey of Sweden.

The interpretation of the XS-data took personnel resources approximately 2 and a half weeks and the XS/P-data 2 weeks, which made about 10 and 16 minutes per km^2 respectively. The same figures for computer time were 0,2 and 1,3 minutes per km^2.

4.5 Statens Kartverk

The interpretation of the Norwegian Mapping Authority (SKV) was done at the panchromatic scene taken on the 23rd of June 1987. The process used in this work was a combination of manual and automatic methods.

- The scheme of the interpretation method was as follows:

1. DATA PREPROCESSING
   - contrast stretch

2. MANUAL INTERPRETATION OF LINE FEATURES BY DIGITIZING

3. INTERPRETATION OF THE OTHER LAND USE CATEGORIES CLASS BY CLASS
   1. thresholding of the grey value interval of the class
   2. colouring of the class
   3. retouching areas that probably belong to the class by painting on the screen

4. FILTERING
   - 3x3 mode filter

The equipment used in this was TERAGON 4000 Image Processing System. For this project the application Image Plus has been used.

The interpretation process took in total 50 hours of personnel resources, which made about 10 minutes per km^2.

CLASS IN BASIC MAP	GL1	GL2	GL3	IFAG	IGN1	IGN2	LMV1	LMV2	SKV
1. WATER	X	X	X	X	X	X	X	X	X
2. RIVER 20-5 m WIDE		X	X		X	X			
3. BROOK 5 m or less		X	X		X				
4. ARABLE LAND/MEADOW	X	X	X	X	X	X	X	X	X
5. FOREST		X	X	X	X	X			X
5.1 CONIFEROUS FOREST							X	X	
5.1.1 PINE FOREST	X								
5.1.2 SPRUCE FOREST	X								
5.2 MIXED FOREST	X								
5.3 DECIDUOUS FOREST	X						X	X	
6. CLEARING/SAPLING STAND	X	X	X			X			X
6.1 CLEARING					X		X	X	
6.2 SAPLING STAND					X		X	X	
7. MARSH	X		X			X	X	X	
7.1 OPEN MARSH		X			X				
7.2 WOODED MARSH		X							
8. EXPOSED BEDROCK		X	X						
9. BUILT UP AREA		X	X		X	X	X	X	
10. QUARRY		X			X	X	X		
11. MAIN ROAD		X	X				X	X	X
11.1 IA (DUAL CARRIAGE)					X	X			
11.2 IB (2-4 LANES)					X	X			
12. SECONDARY ROAD		X	X				X	X	X
12.1 IIA AND IIB					X	X			
12.2 IIIA AND IIIB					X	X			
12.3 CARTROAD					X	X			
13. RAIL ROAD					X		X		
14. POWER LINE					X	X	X		X

Table 4: *Basic Map classes interpreted in different interpretations: GL1 = XS-data (numeric), GL2 = P-stereo pair (visual), GL3 = XS/P-data (visual), IFAG = XS-data (numeric), IGN1 = XS-data (visual), IGN2 = P-stereo pair (visual), LMV1 = XS-data (visual + numeric), LMV2 = XS/P-data (visual + numeric), SKV = P-data (visual + numeric).*

5 Results

5.1 Number of interpreted land use classes

The legend of the Basic Map was used as a basis for interpretations. Thus the interpreted classes were mainly in accordance with this classification. This topographical map contained about 70 land use classes and an effort was made to interpret only a part of them. The participants grouped many classes together and left several classes uninterpreted (see table 4).

The number of the classes varied from 4 to 17, according to the method used. The majority of land cover categories was interpreted visually. The objects which could be identified by means of feature shape (roads and rivers) or texture (built up areas) were recognized better manually than by the numerical methods used in this experiment. On the other hand, the classes which differed only slightly from each other by their spectral signatures (forest categories) could be identified better using computer classification methods. The inhomogeneity of many land use categories and the quite limited spectral resolution of SPOT-data reduced, however, the usefulness of this spectral separability, and the number of the automatically interpreted classes remained low.

5.2 Classification accuracies

5.2.1 Different land use categories

The accuracies were evaluated calculating estimates from the error matrices (linear object excepted). When the exact content of an interpreted land use class was not known, the pilot centre decided which reference class was used for the comparison. In some cases classes were put together as well.

The accuracies of the following classes were evaluated. The estimates were computed using the test image without the boundary pixels of the features on the reference data.

WATER

Features

In every interpretation lakes, ponds, and pools were classified accurately (see table 5). The mean accuracies varied from 97.4 to 99.5 %. In general, omission was higher than commission, especially shorelines were sometimes difficult to classify automatically (see figure 6). Rush vegetation and sediments created some difficulties in the detection of

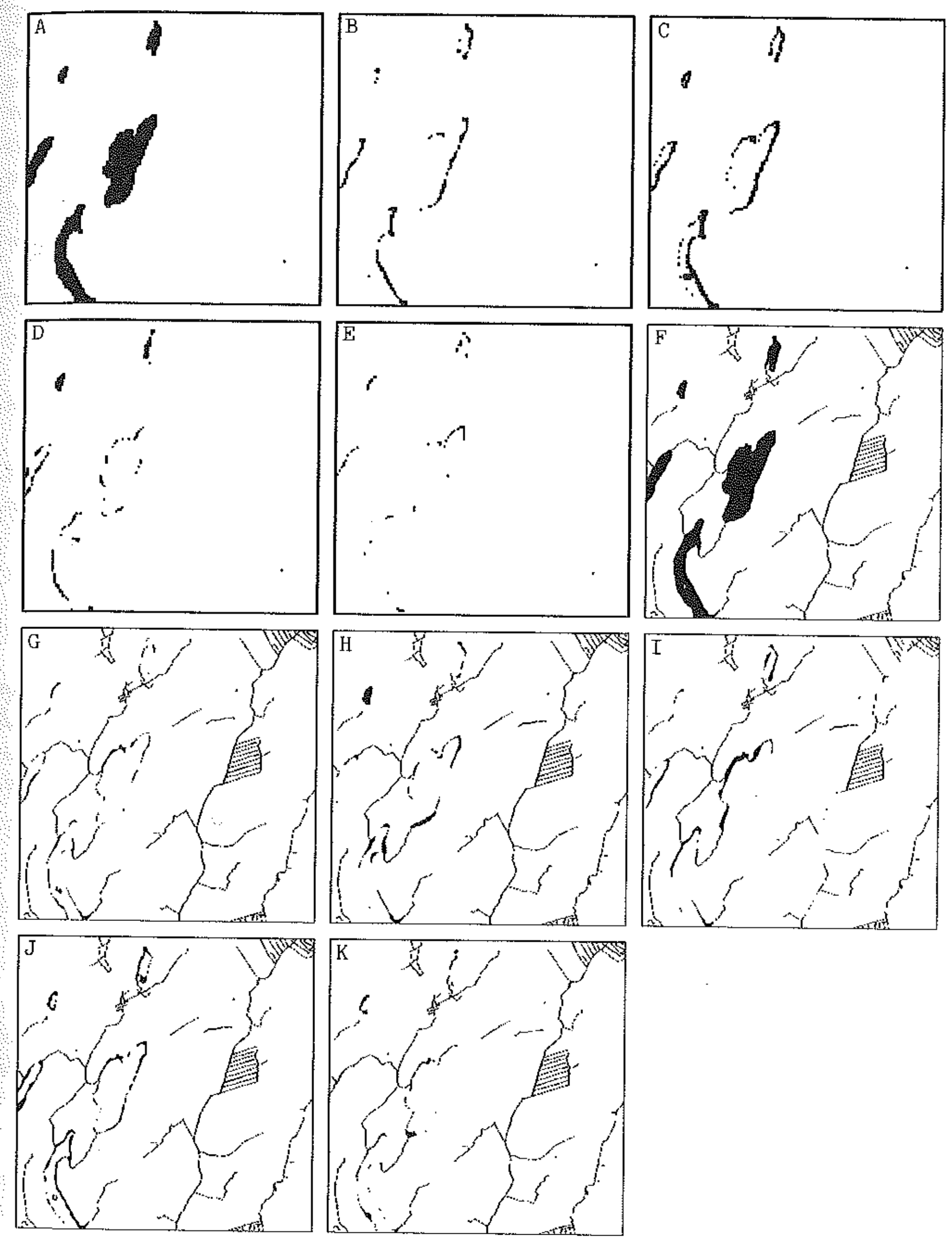


Figure 6: *Water masks and error images of the interpretations (3 km x 3 km). Black represents omission. A = WATER MASK (pixelsize 20 m), B = GL1 (XS), C = IFAG (XS), D = LMV1 (XS) E = IGN1 (XS), F = WATER MASK (Pixelsize 10 m), G = GL2 (2*P), H = GL3 (XS/P), I = IGN2 (2*P), J = LMV2 (XS/P) and K = SKV (P).*

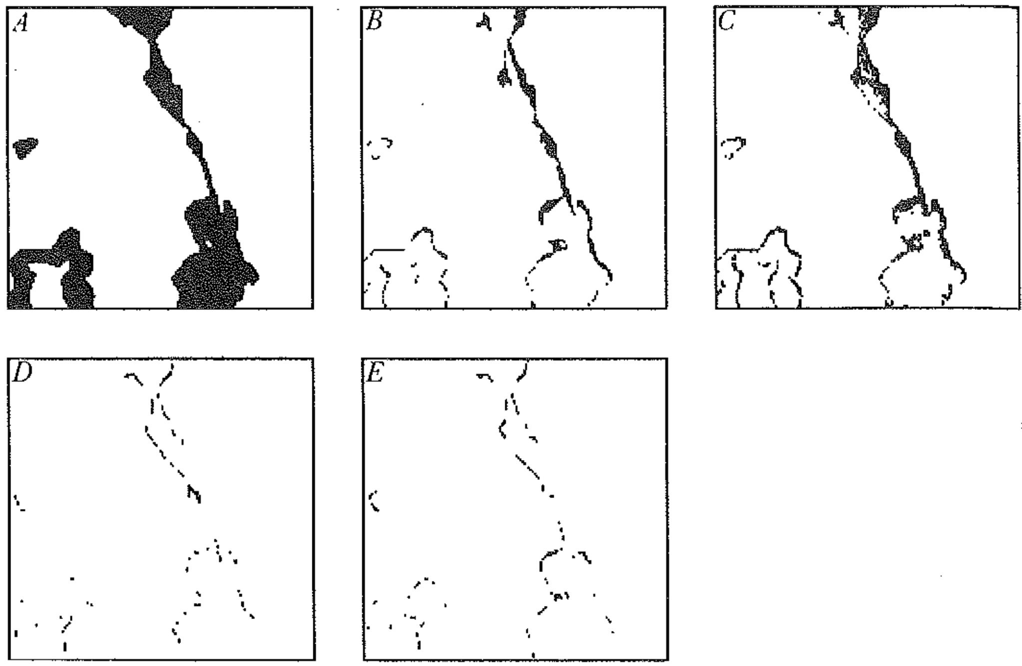


Figure 7: *Example of critical areas (3 km x 3 km) when interpreting water from XS-scene. In some sounds water contains more vegetation and sediments which made it spectrally different and thus often more difficult to interpret automatically. A = WATER MASK (pixelsize 20 m), B = GL1 (numeric), C = IFAG (numeric), D = IGN1 (visual) and E = LMV1 (numeric). In the interpretations black represents omission.*

some heads of bays and sounds (see figure 7). However, omission was not higher than 3.9 % in any interpretation.

The commission was slightly more higher in the visual interpretations than in the automatic classifications. The quite high commission of 4.8 % in the visual interpretation of IGN1 was due to the overclassification of rivers (objects were traced too broadly on the plastic).

The different image data had only a minor effect on accuracies. Anyhow, when the panchromatic data was used alone the definition of shorelines and the detection of some small ponds was more difficult than when XS-data was used. In some cases very dense coniferous forest stands could also be interpreted as small ponds if the infrared information was lacking.

Feature contours

The interpretation of the feature contours (boundary pixels) was most successful when the XS-scene was interpreted manually by IGN1 (83.7 % correct). In the automatic

interpretations of this data, the mixed pixels increased the number of mis-classified boundary pixels. As the water features were on an average larger than those of the surrounding land use classes, the mode filtering reduced this number. When the supervised maximum likelihood classifier was used about 79 % of the boundary pixels were classified correctly (LMV1). In the classifications of the GL1 and IFAG much more pixels remained unclassified or were mis-classified. On the panchromatic scenes the contours were not always visible and in some areas the exact position of the shoreline was difficult to define (see figure 6). Notice that, where the reference images without convolution were used, the interpretation accuracy estimates of the interpretations of the XS-data and the P-data are not directly comparable, because the rivers appeared on the ground truth image with 10 m x 10 m pixelsize.

Rivers

A part of the rivers could be interpreted visually. Using the panchromatic stereo pair or the P/XS-data the omissions of the rivers wider than 5 m varied from 6.2 to 28.6 %. The best result could be reached when the interpretation was performed on the analytical stereo plotter. The interpretation of the smaller rivers was less accurate. The resolution of the XS-data was not good enough for classifying accurately the relatively narrow rivers met in the test area.

AGRICULTURAL LAND/MEADOW

The agricultural lands in the test areas consisted of fields of various sizes and different shapes. These fields were also spectrally very heterogeneous, which was partly due to the date of the registration of the scenes (early stage of the growing season). This fact had effect on the choice of methods for interpreting this land use category. For example, in the interpretations of LMV, the fields were interpreted manually, because they considered that all spectral field classes could not be discriminated well enough from other land use classes automatically.

The agricultural lands were tested as one class. In some interpretations the meadows were included in the unclassified class and in the others they were combined with the agricultural lands. The meadows covered less than one per cent of the test area, thus the effect of this choice on the estimates was minor.

Features

The mean accuracies of this class varied from 84.9 to 96.6 % and the best results were obtained using manual methods (see table 5). The omission and the commissions varied from 18.0 to 2.7 and from 16.3 to 2.0 %, respectively.

In the automatic classifications, several subclasses were used for interpreting fields (IFAG 11 and GL1 4). However, some areas could not be detected. The omission was

INTERPRE-TATION	LAND COVER CLASS	OBJECT ACCUR.	INTERP. ACCUR.	MEAN ACCUR.	KAPPA COEFF.	AREA (Ref.data)
GL1 (XS)	1. WATER	100.0	98.5	99.2	1.000	10.1
	2. AGRICULTURAL LAND	89.6	95.5	92.5	0.846	24.7
	3. PINE FOREST	56.7	48.9	52.5	0.514	11.7
	4. SPRUCE FOREST	90.0	42.3	57.5	0.872	24.0
	5. MIXED FOREST	11.9	46.2	18.9	0.083	6.1
	6. DECIDUOUS FOREST	48.8	20.7	29.0	0.482	2.9
	7. SAPLING STAND/CLEARING	66.0	44.4	53.1	0.633	10.0
	8. MARSH	2.5	4.8	3.3	0.020	0.7
IFAG (XS) (original)	1. WATER	100.0	96.1	98.0	1.000	10.1
	2. AGRICULTURAL LAND	83.7	86.0	84.9	0.758	24.7
	3. FOREST	84.5	93.3	88.7	0.749	44.7
(mode filtered)	1. WATER	100.0	97.1	98.5	1.000	10.1
	2. AGRICULTURAL LAND	85.2	89.7	87.4	0.780	24.7
	3. FOREST	84.5	95.5	89.7	0.750	44.7
IGN1 (XS)	1. WATER	95.2	99.7	97.4	0.941	10.1
	2. AGRIC.LAND/MEADOW	94.4	90.2	92.3	0.917	25.6
	3. FOREST	88.2	95.5	91.7	0.806	44.7
	4. SAPLING STAND/CLEARING	82.0	30.4	44.4	0.805	10.0
	5. MARSH	25.8	47.5	33.5	0.255	1.5
	6. BUILT UP AREA	51.1	85.2	63.9	0.500	5.5
	7. QUARRY	52.7	77.2	62.6	0.525	0.5
LMV1 (XS)	1. WATER	99.7	99.3	99.5	0.996	10.1
	2. AGRIC.LAND/MEADOW	98.0	92.4	95.1	0.970	25.6
	3. CONIFEROUS FOREST	98.3	67.7	80.2	0.974	41.8
	4. DECIDUOUS FOREST	19.1	79.3	30.7	0.181	2.9
	5. SAPLING STAND/CLEARING	67.3	62.6	64.9	0.648	10.0
	6. MARSH	10.6	72.3	18.5	0.091	1.5
	7. BUILT UP AREA	68.1	92.3	78.4	0.674	5.5
	8. QUARRY	71.5	85.0	77.7	0.714	0.5
GL2 (2xP)	1. WATER	98.7	98.4	98.5	0.985	7.3
	2. AGRICULTURAL LAND	97.4	95.8	96.6	0.957	35.0
	3. FOREST	76.9	97.7	86.0	0.629	39.5
	4. SAPLING STAND/CLEARING	63.5	16.4	26.1	0.588	13.5
	5. BUILT UP AREA	91.7	35.2	50.9	0.917	2.7
	6. QUARRY	93.4	93.9	93.7	0.934	0.4
GL3 (XS+P)	1. WATER	99.9	99.1	99.5	0.999	7.3
	2. AGRICULTURAL LAND	97.2	90.6	93.8	0.952	35.0
	3. FOREST	84.4	82.5	83.4	0.750	39.5
	4. BUILT UP AREA	28.2	63.1	39.0	0.277	2.7
IGN2 (2xP)	1. WATER	97.9	99.2	98.5	0.977	7.3
	2. AGRICULTURAL LAND	89.5	97.3	93.3	0.827	35.0
	3. FOREST	91.1	89.8	90.4	0.854	40.5
	4. SAPLING STAND/CLEARING	61.9	44.3	51.6	0.569	13.5
	5. BUILT UP AREA	46.8	69.9	56.0	0.465	2.7
	6. QUARRY	59.7	47.8	53.0	0.595	0.4
LMV2 (XS+P)	1. WATER	100.0	99.0	99.5	1.000	7.3
	2. AGRICULTURAL LAND	97.0	96.2	96.6	0.949	35.0
	3. CONIFEROUS FOREST	89.1	86.3	87.7	0.824	38.2
	4. DECIDUOUS FOREST	10.2	50.8	17.0	0.098	2.3
	5. SAPLING STAND/CLEARING	59.5	58.9	59.2	0.543	13.5
	6. BUILT UP AREA	82.4	57.1	67.5	0.823	2.7
SKV (P)	1. WATER	99.1	99.2	99.2	0.990	7.3
	2. AGRICULTURAL LAND	92.7	82.0	87.0	0.878	35.0
	3. FOREST	86.4	94.3	90.3	0.780	40.5
	4. SAPLING STAND/CLEARING	34.6	39.6	36.9	0.262	13.5

Table 5: *Accuracies of different land cover classes of the interpretations. Testing was made without feature boundary pixels.*

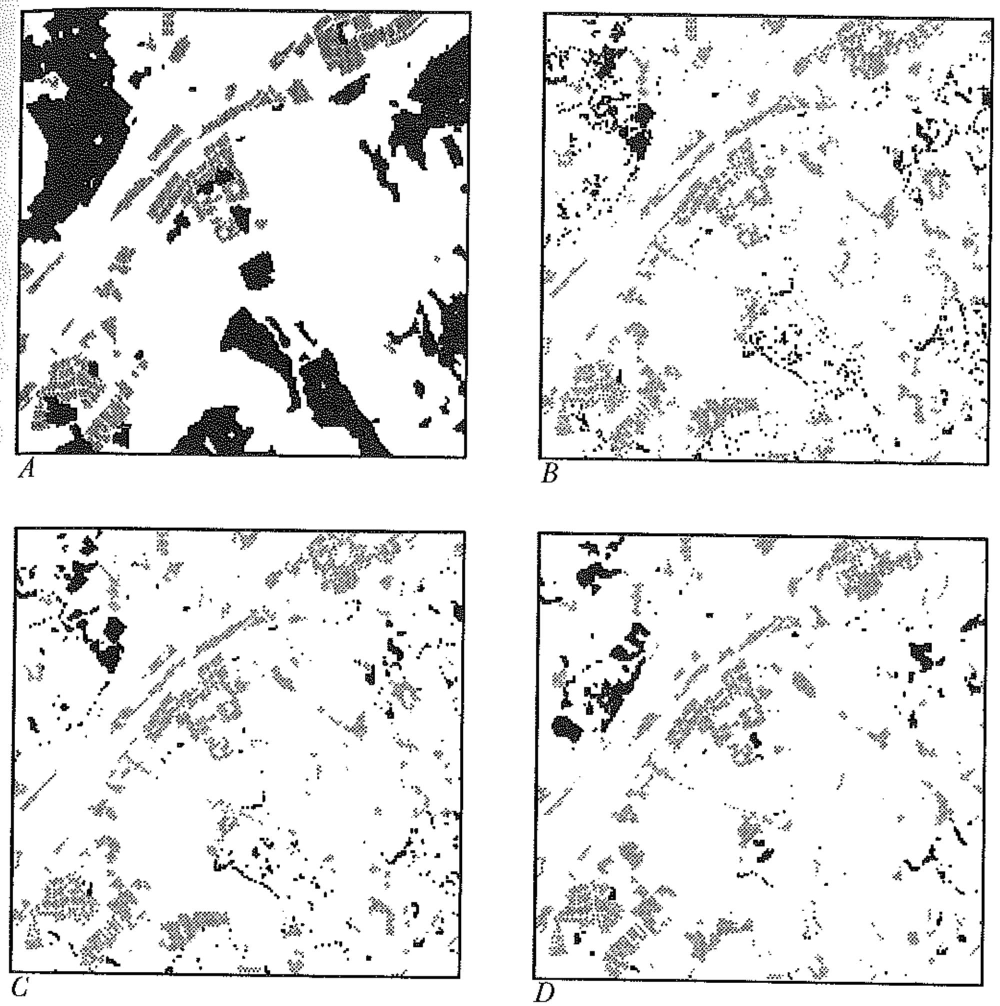


Figure 8: *Example of critical areas (4 km x 4 km) in the automatic classification of agricultural areas. A = reference data, B = IFAG, C = IFAG (mode filtered by the pilot centre), D = GL1. In the reference data black = field and grey = built up area. In the interpreations black (large dot) represents omission and grey (small dot) commission. In the scene (D) omitted areas were classified as sapling stands or unclassified, and in the scenes (B) and (C) they were mainly classified as forests. The commission of these interpretations was mainly due to the misclassification of built up areas and to some extent the overclassification of young sapling stands.*

mainly due to the mis-classification of small spectrally unrepresentative patches in the fields and numerous mixed pixels resulting from the spectral mosaic within the features. A part of the fields remained unclassified as well. In the digital interpretations, the commission was higher than the omission, and it was mainly due to the systematic classification of the built up areas as fields (see figure 8).

In the visual interpretations, a great part of the omission was due to the misidentification of the agricultural lands. Some fields were detected correctly but classified as other land use classes. In these cases the interpretation characteristics like tone, hue, shape, texture, or site were not selective enough for discriminating fields from other land use categories. Especially small fields surrounded by forests could be blended with sapling stands or clearings (see figure 9 and appendices 8.1-8.9). The mosaiclike patterns in some areas were difficult to distinguish from built up areas and newly ploughed fields from quarries. Blurred feature boundaries on the scenes and drawing precision had effect on the object accuracies in these works as well. The commission was lower than the omission when using manual methods apart from the interpretation of IGN2, where some large sapling stand features, deciduous forests, thin pine forests, or wooded marshes could not be identified correctly and were classified as agricultural lands.

The multispectral scenes contained more spectral information about fields than a single panchromatic scene, but this information was not always relevant to topographical mapping and helped only in some cases the interpretation of fields. When the interpretation was made visually, the panchromatic stereopair was as suitable as XS-scene for discriminating agricultural lands from other land use categories . The improvement of the interpretability of the panchromatic stereopair compared with a single panchromatic scene was due more to multitemporal data merging than to the stereoscopic effect.

Feature contours

More than a quarter of pixels on field masks were boundary pixels. The omission of these pixels (meadows included) varied from 13.5 to 35.3 %.

When the XS-data was used alone, the best results were reached using automatic classifications (GL1 13.0 % and IFAG 21.2 %). The number of omitted pixels was higher when the interpretation was made visually (LMV1 23.5 % and IGN1 30.4 %). This was due to blurred feature contours, the drawing precision, and the omission of whole features.

When the higher spatial resolution data was used, the best results were reached using XS/P-combination image and making the manual interpretation on the screen (LMV2 18.6 %). The same data interpreted on the paper print 1:50000 gave a less satisfactory result (GL3 29.1 %) and the main reason for this was the lack of experience of the interpreter. In the interpretation of the panchromatic stereo pair on the paper print, the

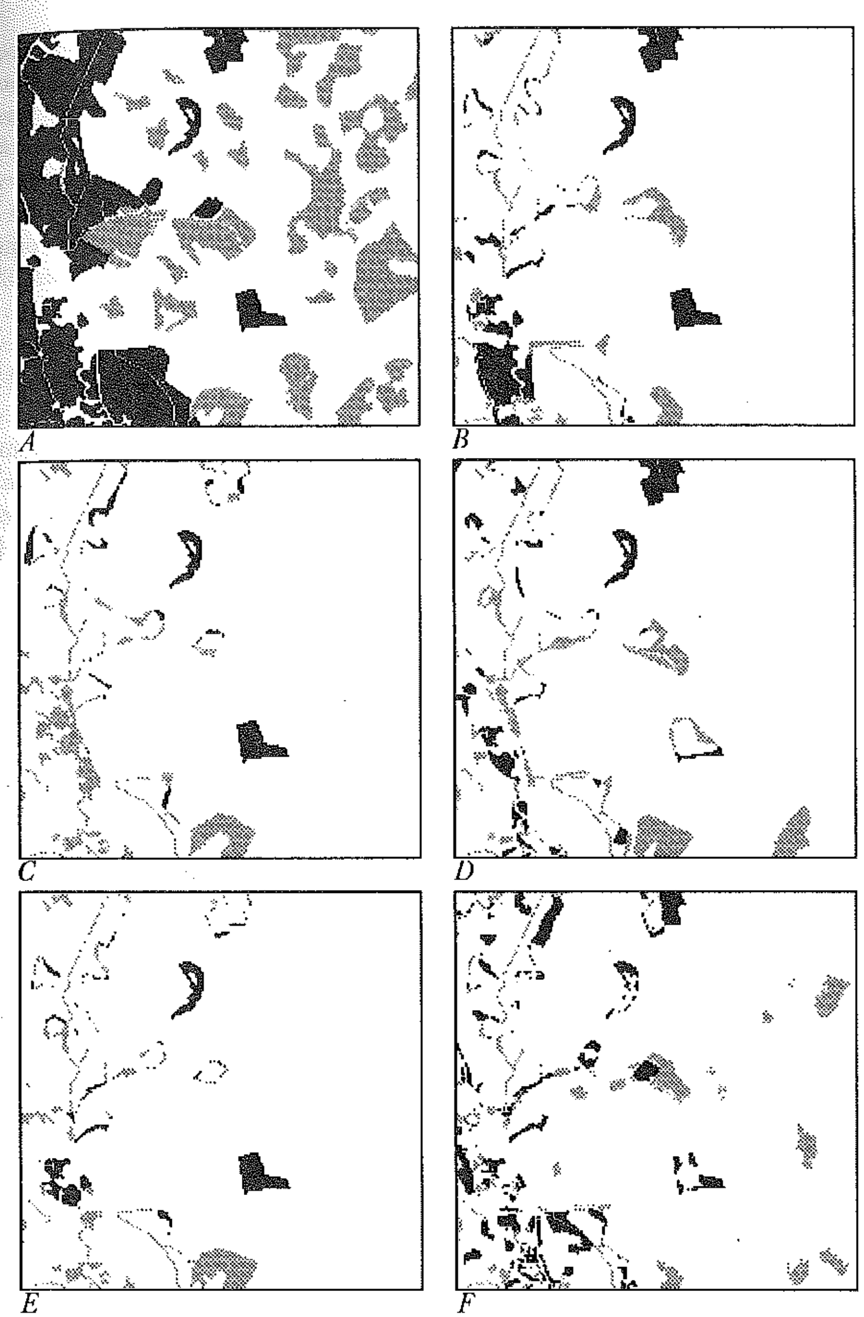


Figure 9: *Example of critical areas (2 km x 2 km) in visual interpretation of fields. In the reference data black = field and grey = sapling stand or clearing. In the interpreations black (large dot) represents omission and grey (small dot) commission. Small field features were difficult to distinguish from sapling stands or clearings when they were surrounded by forests. A = ref. data, B = GL2, C = GL3, D = IGN2 E = LMV2 and F = SKV.*

omission of the boundary pixels was 19.7 % (IGN2). Contrary to what was expected when the interpretation of the same stereo pair was performed on the stereoplotter, more boundary pixels were missed (GL2 25.1 %). The difference was mainly due to the general overclassification of fields in the interpretation of IGN2 , less features were omitted and many interpreted features were drawn as too large, while in the interpretation of GL2 the commission was low and the features were often interpreted as too small. The feature contour extraction was less successful when a single panchromatic scene was interpreted using the combination of manual and automatic methods (SKV 35.3 %).

As to the boundary pixels the omission accuracy figures of the interpretations of the 10 m data were not directly comparable with those of the interpretations of 20 m data. The reason for this is that the same field feature did not consist of the same number of contour pixels; different scanning resolution and resampling had effect on the shape of the features on the masks; and drawing precision influenced more the results; when the 10 m pixelsize was used at the same scale than the 20 m data. The geometry had some effect on the estimates as well.

FOREST

Even if the forests of Southern Finland consist only of a few tree species, they are very variable. Thickness, age, lesser vegetation, soil type, humidity of soil, combination of species, etc. vary from one area to another. Thus significant spectral variations in reflectance between features in the test areas were not always meaningful for topographical land use mapping. The size of forest subclass features was often quite small, and boundaries between them were in many cases hazy as well.

Features

The forests of the test area could be classified accurately only when one forest class was used. The spectral signatures of different forest subclasses were highly correlated in the portions of the spectrum registered by SPOT. When they were interpreted separately using supervised classification methods, the accuracies remained very low (see table 5). Even the deciduous forests could not be classified well in the test area, because they could not be discriminated from sapling stands, some fields, and mixed forests. In the classification of IFAG, forests were classified into three spectral classes. The first of them (79 % of classified forests) corresponded to pine-, spruce-, decidious, and mixed forests in the field, the second one (1 %) to rush vegetation, and the third one (20 %) to sapling stands, fields and all kinds of forests (appendix 9.2).

When the testing was made by using one forest class, the mean accuracies varied from 83.4 to 91.9 %. There is no systematic difference in mean accuracies between the visual and the automatic methods used. The results obtained, when the panchromatic data was used alone, were similar to those of the XS data (see IGN1 and IGN2 in table 5).

The omissions were high in two interpretations. In the classification of LMV1 (XS-data) the omission of 24,0 % was due to an important systematic overclassification of the marshes. Especially a lot of pine forests (more than 45 %) were classified as marsh. If the classified forests and the marshes were combined together and tested with the forested marshes and all forest classes in the reference data, the omission was only 2.8 % . In the visual interpretation of GL3 (XS/P-data) 18.4 % of the test area was unclassified, thus a large part of forested area, especially some sparse forests, was not classified at all. In the rest of the interpretations, the omission varied from 2.3 to 11.3 %, and it was mainly due to the classification of sparse forest as sapling stands or the classificaton of deciduous forests as fields. In the automatic classifications many sparse pine forests remained unclassified as well.

There were 4 interpretations where the commission was higher than 15 per cent. Three of them had (except GL3 see above) very small omission. Thus, in general, a small omission meant a high commission and vice versa, because some forested areas had important spectral overlapping with other land use categories (appendicies 8.1-8.9).

Feature contours

The contours of the forest features were difficult to extract exactly in many cases. In general some pixels around the contour lines were omitted or the features were interpreted as slightly too large (see figure 10). In the visual interpretations this inaccuracy was mainly due to drawing precision (especially when the interpretation was made on a 1:50000 scale) and blurred feature boundaries, when the difference between the contrast of two classes was low (e.g. deciduous forest contra field with green crop). In the automatic interpretations mixed pixels were the main cause for omisson and commisson. The geometry of the scenes had effect on the contour extraction as well.

SAPLING STANDS/CLEARINGS

Sapling stands and clearings were difficult to discriminate from each other, because young growing forests were spectrally very similar to clearings. The other difficulty of the classification was that old sapling stands were transformed into young forests gradually.

In this study the sapling stands and the clearings were tested as one class. The sapling of this class contained all young growing forests whose tree height was less than two meters (criteria for Basic Maps).

This class could not be interpreted accurately in any work. The best mean accuracy was 64.9 %(LMV1), and it was obtained when the class was classified using the maximum likelihood classifier after masking the agricultural lands which had been interpreted visually beforehand. In the other interpretations the high commission or the high omission reduced the mean accuracies (see table 5).

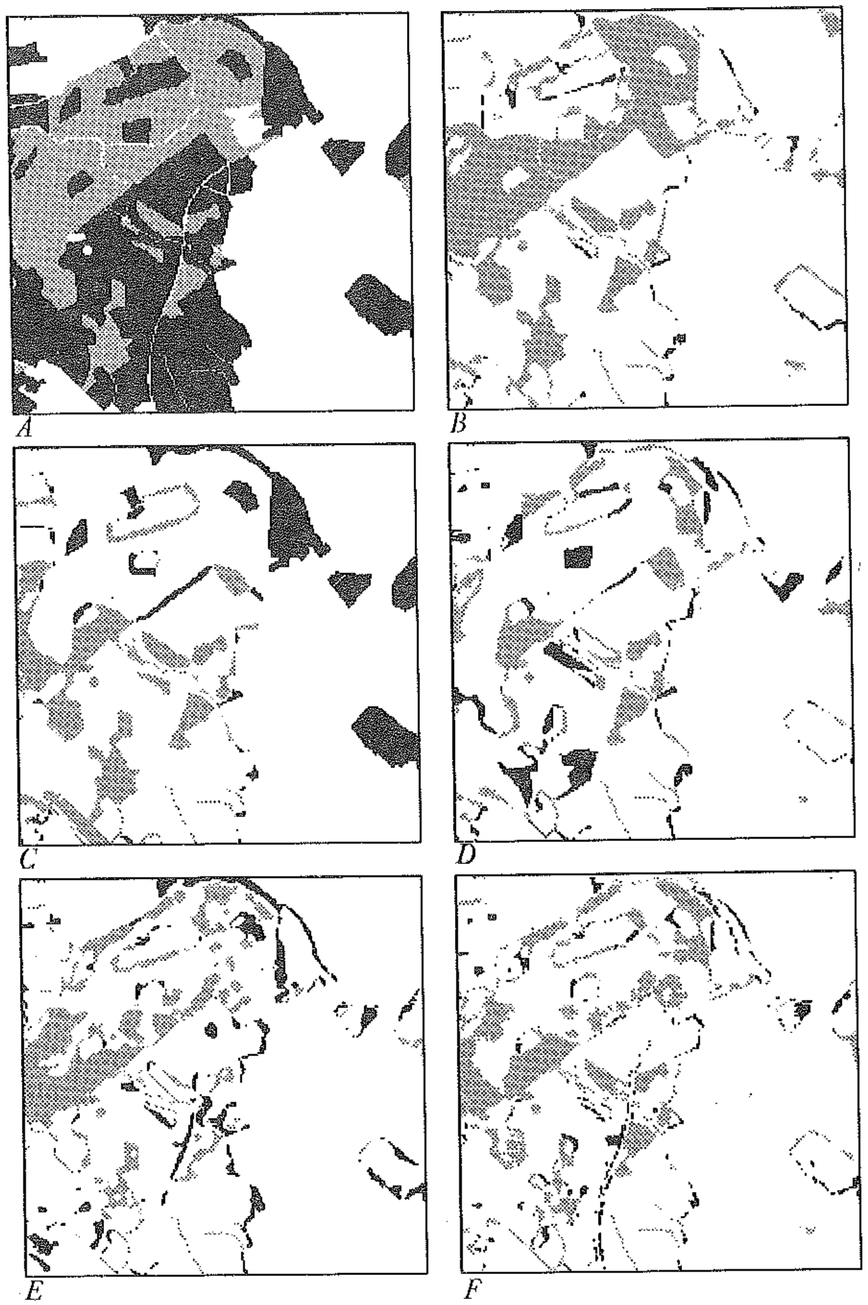


Figure 10: *Example of critical areas (2 km x 2 km) in visual interpretations of forests. A = reference data, B = GL2, C = GL3, D = IGN2, E = LMV2, and F = SKV. In the reference data black = coniferous forest, dark grey = deciduous forest, light grey = sapling stand/clearing, and white = other. In the interpretations black (large dot) represents omission and grey (small dot) commission.*

The omission was mainly due to the interpretation of sapling stands into marshes (LMV1), forests (GL2, IGN1, IGN2, SKV)(appendices 8.3, 8.5 and 8.7 and figure 10) or unclassified category (GL1). The overclassification was caused for the most part by mis-classification of sparse forests and some fields with crop just come up.

MARSH

Neither open nor forested marshes could be interpreted accurately in any interpretation. The spectral signatures of these classes were not different enough for discriminating them from forests.

BUILT UP AREA

This land use class was interpreted only visually. The test areas for the XS-data and for the other imagery were different; the first area covered relatively large densely populated areas, while in the second one there were only small features. Thus the interpretation results of the different test areas could not be directly compared.

The interpretations were mainly made by drawing large homogeneous areas and not by separating actual, quite small built up features. This generalization had an effect on the estimates (overclassification).

The mean accuracies of this class varied from 63.9 to 78.4 % for the first test area and from 39.0 to 67.5 % for the second. In the first case a high commission reduced these figures, while the omission in these interpretations was quite low (see table 5). In the interpretations of the second test area, a lot of features were omitted as well.

The basic characteristics of visual interpretation of the built up areas were tone (hue), pattern, shape, site, and association. In many cases they were the same as those of the agricultural lands. Thus, when the contextual information, like a road network or an urbanized area, was lacking, the confusion between these two classes was often significant.

QUARRY

Sand and gravel pits were interpreted in four works. In one of them the classification was made numerically after interpreting the agricultural lands and masking them from the image. In the other works the interpretation was made manually.

The quite extensive quarries could be interpreted quite accurately in some cases (see table 5). The best mean accuracy was 93.7 % (GL2). However, this class covered only a very small part of the test areas and consisted of a small number of objects. Thus a misclassification of one large object had a significant effect on the estimates.

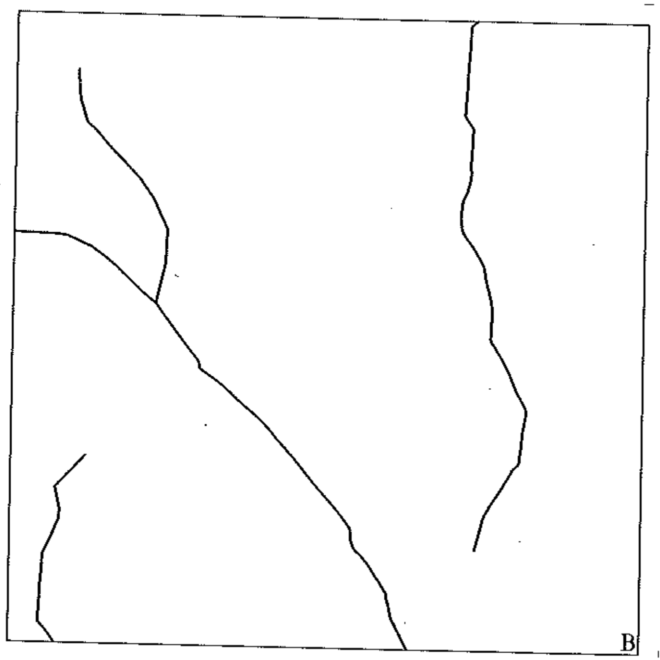
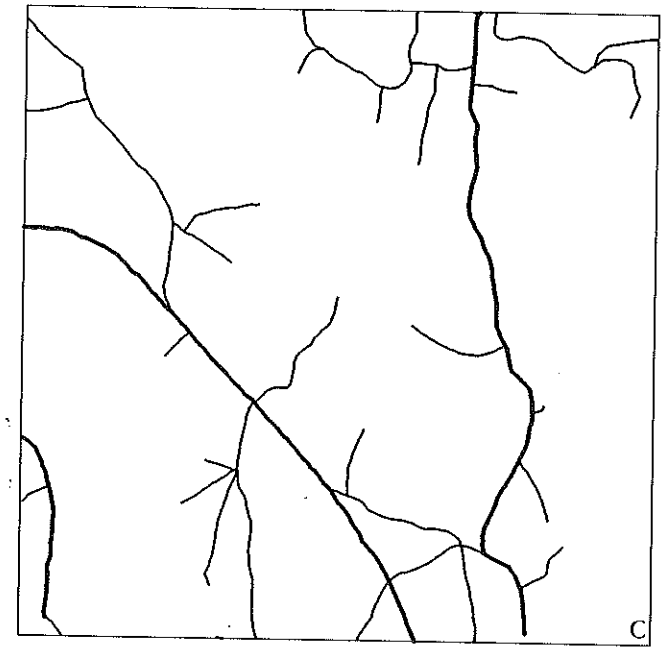


Figure 11: *Example of visual interpretation of roads. A = Basic Map road network (bold line = IIAB, medium line = IIIAB, and, thin line = cartroad), B = LMV1 (XS), C = GL2 (2*P) and D = LMV2 (XS/P). (Area = 5 km x 5 km).*



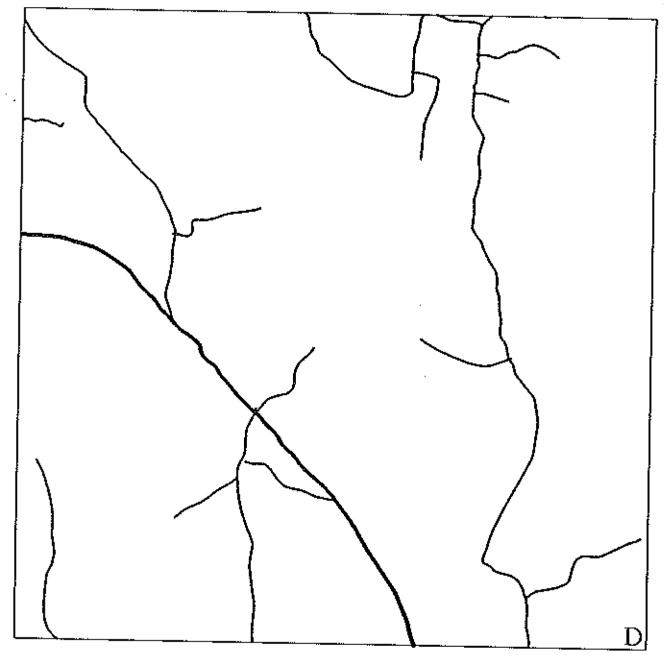


Figure 11: *(Continued)*

The omission of this class which varied from 52.2 to 6.1 % was mainly due to the interpretation of small pits as fields or built up areas. Barren lands in built up areas and ploughed field caused some commission as well. When the quarries were covered by vegetation they could be interpreted as forested area, too.

ROADS

Roads were interpreted in the visual interpretations. In the works of IGN different road classes of the Basic Map were interpreted. In the rest of the interpretations the roads were classified into two classes.

The road network could be interpreted accurately when the 10 m resolution data was used. All the roads wider than 5 m could be detected on the scenes. From the single lane roads (3-5 m) about 90 % were interpreted (see table 6 and figure 11). When the panchromatic stereo pair and the analytical stereo plotter were used (GL2), even more than 54 % of the cartroads could be identified on the scenes. The commission of the roads for these data varied from 0.3 to 8.0 %.

When the XS-data was used alone, the motorways and the 1B roads (2-3 lanes and wider than 7 m) could be interpreted well (table 6). The omission of the road class II (2 lanes and 5-7 m wide) varied from 19.9 to 16.3 %. The total commission of the roads was between 3.4 and 3.6 % in these interpretations.

The classification of roads was more difficult than identifying them as roads. If the Basic Map road classes were used (IGN1 and IGN2), the confusion between these classes was important. When only two road classes were used the commission and the omission were lower in some interpretations (GL2 and LMV1) (see appendix 10).

The interpretability of roads depended highly on their surroundings and age. When the XS-data was used, the roads that could not be detected often were surrounded by freshly ploughed fields or built up areas. The new roads appeared more prominently on the scenes than the old ones. Thus they were interpreted better and often put into higher class than on the map. Confusion between road classes was also due to the subtle difference between some map classes.

MAP CLASS	IGN1 (XS)	LMV1 (XS)	GL2 (2xP)	GL3 (XS+P)	IGN2 (2xP)	LMV2 (XS+P)	SKV (P)
I A	100.0	100.0	-	-	-	-	-
I B	96.3	98.0	-	-	-	-	-
II AB	80.1	83.7	100.0	99.6	100.0	99.8	98.5
III AB	38.3	48.7	90.4	81.8	89.5	91.0	81.9
CARTROAD	5.0	5.0	54.4	10.9	31.6	35.1	-

Table 6: *Correctly interpreted roads (%) in the interpretations.*

The commission of roads was mainly due to the joining of two separated roads together when that seemed logical, or the drawing of an invisible part of the road in the wrong place. In some cases small rivers or brooks and powerlines were interpreted as roads as well.

5.2.2 Overall accuracies

The total accuracies were tested using the original classification of the interpretations and the optimized classification made by the pilot centre. The optimization was made because some classes in the interpretations were categorized systematically into wrong land use categories (training data was limited and the participants could not realize field verifications after the classification). These new categorizations also made possible a comparison of the results obtained by different interpretation methods and by using different imagery.

In the optimization the interpreted classes were defined by reasonable informative land use classes so that the total accuracy of the interpretation was as high as possible. This was made by combining and redefining (when the confusion was systematic) the interpreted classes according to the confusion matrices. The new classification was tested like the original one, using the ground truth image without the pixels of the feature boundaries.

The total accuracies varied from 69.4 to 89.2 % (with feature boundaries 52.8-79.8 %). Kappa indices were between 0.623 and 0.844 (0.433-0.701). When the optimized classifications were used, the accuracies varied from 83.5 to 97.2 % and Kappas from 0.758 to 0.952 (see table 7).

The best results were obtained when visual interpretation methods or a combination of visual and automatic interpretation method were used. The estimates of these cases were higher and more land use classes could be interpreted accurately.

Different image data had no apparent effect on the total estimates. When similar categorizations and methods were used the differences between Kappa coefficients and total accuracies of different interpretations were small (see IGN 1 and IGN2 and LMV1 and LMV2 in table 7).

5.2.3 Time consumption

As several factors, like the experience of the interpreter, the precision of the work, the size of the smallest interpreted feature, the size of the test area, the operationality of the method, etc., had an important effect on the man hours consumed in an interpretation,

INTERPRETATION	TEST I		TEST II		TEST III	
	TOTAL ACC.	KAPPA	TOTAL ACC.	KAPPA	TOTAL ACC.	KAPPA
GL 1 (XS) Num. 8 Classes	69.4	0.623	52.8	0.443	88.8	0.831
IFAG (XS) Num. 4 Classses	82.5	0.747	73.5	0.601	85.8	0.786
IFAG (XS) Num*) 4 Classes	84.6	0.776	75.7	0.631	88.2	0.821
IGN 1 (XS) Vis. 7 Classes	89.2	0.844	79.8	0.701	93.8	0.904
LMV 1 (XS) Vis./Num. 8 Classes	81.8	0.761	68.6	0.605	96.1	0.939
GL2 (P-STEREO) Vis. 7 Classes	86.3	0.794	76.2	0.634	96.6	0.942
GL 3 (XS/P) Vis. 4 Classes	83.5	0.758	71.1	0.586	83.5	0.758
IGN 2 (P-STEREO) Vis. 7 Classes	88.1	0.821	77.1	0.659	94.0	0.899
LMV 2 (XS/P) Vis/Num. 6 Classes	87.6	0.818	74.6	0.643	97.2	0.952
SKV (P) Vis/Num 4 Classes	82.7	0.744	73.6	0.608	89.8	0.823

Table 7: *Total accuracies and Kappa coefficients of the whole interpretations. Testing was made as follows: Test I = reference data was used without feature boundary pixels, Test II = reference data was used with feature boundary pixels, and Test III = reference data was used without feature boundary pixels and the classification was optimized. * = classification mode filtered by the pilot centre.*

the time consumption (see chapters 4.1-4.5) gave only a very general idea about the efficiencies of the different types of methods. The time consumed per km^2 varied from 10 to 46 minutes. When the interpretation was made numerically, the classification of one km^2 required from 0.4 to 1.4 CPU minutes.

6 Conclusions

6.1 General conclusion of interpretability of SPOT data

The series of interpretation experiments described above were intended to investigate the possibilities of using the SPOT imagery for compiling physical and cultural features for topographical maps. They were realized using different SPOT scenes and different interpretation methods. Contrary to the expectations many of the original participants of this study did not return any interpretation. Thus the total number of interpretations remained quite low and some material type was interpreted only once. As there were several factors which had effect on the quality of an interpretation it was sometimes difficult to discriminate the share of the material from other factors (difference between test areas, experience of the operator, etc.) when analyzing the results for lack of comparable interpretations.

In this study the interpretation process did not always correspond to "the normal one", e.g., field checkings, which could be important for selecting training areas or categorizing interpreted classes, could not be realized during the process. Although this fact was taken into consideration as far as possible when analyzing the results, it could have some effect on them.

However, with the results of the interpretations the following conclusions can be drawn:

SPOT images, in themselves, do not provide all of the land cover information required for a topographical map. From areal features in general three classes can be interpreted accurately. Some other classes can be interpreted fairly well in certain conditions.

The water areas, with the exception of some narrow sounds or ends of bays with thick rush vegetation, can be detected totally. However, feature boundary pixels are often omitted when the interpretation is made numerically or the only panchromatic data are used in a visual interpretation. In general omission was higher than commission; only a slight over-classification can be found when the infrared channel is lacking.

Generally the agricultural areas can be interpreted accurately. Some critical areas can be omitted both in visual and in automated interpretations. The commission is much higher in numerical classifications and, in general, the visual method seems to be better for interpreting fields. Many feature boundaries are difficult to detect numerically and visually.

The forests can be interpreted accurately if only one forest class is used. Some confusion with sapling stands can be avoided only by combining these classes together or changing their informative criteria.

Large densely populated areas can be interpreted visually quite well if some generalization is accepted. Many smaller built-up areas can often be detected, but their classification as built-up areas is more difficult.

The quarries are visually detectable on the scenes. However, their identification as quarries is not always accurate.

Line features are clearly visible on the SPOT scenes. Major roads are prominent on all images and they can be interpreted well visually. The detection and identification of smaller roads is very high when the 10 m resolution data is used. However, classifying roads accurately is not possible only by image interpretation.

Rivers wider than 5 m can be interpreted quite well when the interpretation is made using 10 m resolution data and manual methods. Powerlines can be detected well when they are surrounded by forests, otherwise they are visible only occasionally.

When the number of interpreted land cover classes is low, it seems that there are no important differences between the panchromatic stereopair and the XS-scenes as to the interpretability of areal features. For linear features the 10 m resolution data is clearly superior.

In general visual interpretations give better results than numeric classifications. More classes can be interpreted manually and the mean accuracies of the classes, which can also be classified numerically, are as high or better in visual interpretations than in automatic classifications. The combination of manual and automated methods seems to be the optimum solution.

6.2 Remarks on results

There are several factors which have an effect on the interpretability of SPOT imagery and thus its suitability for topographical mapping. Some of them are connected with the general characteristics of interpretation of SPOT scenes and others with the base of this study.

Imagery

The original imagery is the most crucial factor when considering the reliability of classification of a satellite image. Because of the high correlation between visible bands of the XS-data its multispectral information is practically limited to two bands. These two bands are not sufficient for separating some land cover categories which have different spectral signatures. This fact limits the usability of the XS-data in numerical classifications.

The higher ground resolution of P-data provides tremendous improvements in the interpretation of linear features. However, the better texture of this data does not improve the identification of the areal land cover classes in the test area.

Because of the poor stereo effect of the panchromatic stereo pair used in this investigation, the improvement of this data in the identificaton of some land cover categories comparing with a single panchromatic scene was mostly due to the multitemporal aspect of this data and the matching of two images together. Thus it is not possible to conclude the potential improvement due to the stereo viewing. For the linear feature extraction the interpretation performed on an analytical stereoplotter is better than the interpretaton of the same pair on paper prints. Otherwise both technics give similar results.

The effect of the registration date on the interpretability was not studied in this investigation. However, it seems to have an influence on the interpretation of some land cover classes.

Interpretation methods

The interpretation methods used in this investigation are quite ordinary. All numerical interpretations were made by pixel based classification and, in most cases, using operational classifiers. This fact makes results more comparable with many other studies made in similar conditions, but all possibilities of automated classification of SPOT imagery cannot be evaluated.

The visual interpretation of SPOT scenes resembles greatly the normal aerial photo interpretation, only, there are less basic interpretation characteristics when this data is used. Added to the quality of the imagery, the skill and the experience of the interpreter seems to be the most important factors when interpreting features from SPOT imagery. The good imagery cannot give good results if the interpretation process is not well performed (e.g GL3). The familiarity with the landscape could have an effect on the results as well. It would be important to have more interpretations to surely conclude the interpretability of different SPOT scenes.

Training material

The trainig material in this investigation is easy to get and thus it is operational. It seems to be sufficient for most of the interpretation methods. However, the lack of more detailed information about the land cover of the test area could have an effect on the realization of some interpretations and their results.

Test area

The test areas used in this study represent a typical irregular landscape in Southern Finland, and they provide a rigorous testing ground for assessing SPOT image capabilities for operational topographical mapping. The results obtained in this study can mainly be generalized to other parts in this country. However, there are several less complex areas with larger and more homogeneous land cover features, and the interpretation of SPOT imagery can give better results there.

7 SPOT-data in topographical mapping

Plan and height accuracies seem to be satisfactory for map compilation at 1:50000 scale when the panchromatic stereo pair is used (Gugan & Dowman 1988, Konecny et al. 1987, Denis 1987 etc.). Reliable extraction of land use information is less satisfactory when SPOT data is used without additional spatial information. However, this data can be useful to some extent when plotting topographical maps.

There are some important considerations when concluding the suitability of SPOT data in operational map compilation:

1. SPOT-data cannot be used as an only land use information source, if the geographic information required for existing Finnish topographical maps at 1:50000 is needed.

2. When SPOT data is used in the interpretation of a part of the physical and cultural features, visual interpretation is recommended if only pixel based numerical methods are available.

3. SPOT data has a potential for providing data for map revision, especially for keeping road networks up to date.

4. If the SPOT data is used in operational works, the availability of imagery within the period and region required must be guaranteed.

5. For regions where no good topographical maps exist, the SPOT data is a potential major cartographic data source (Gastellu-Etchegorry 1989) for producing "primary maps".

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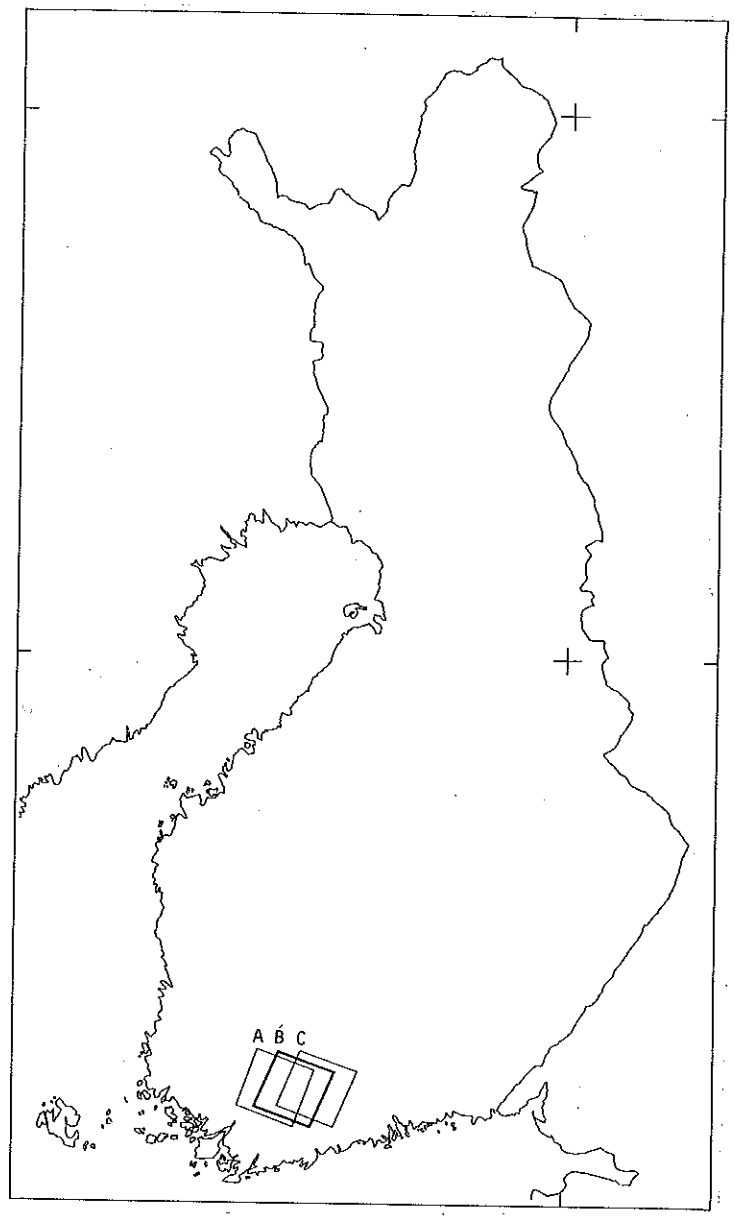
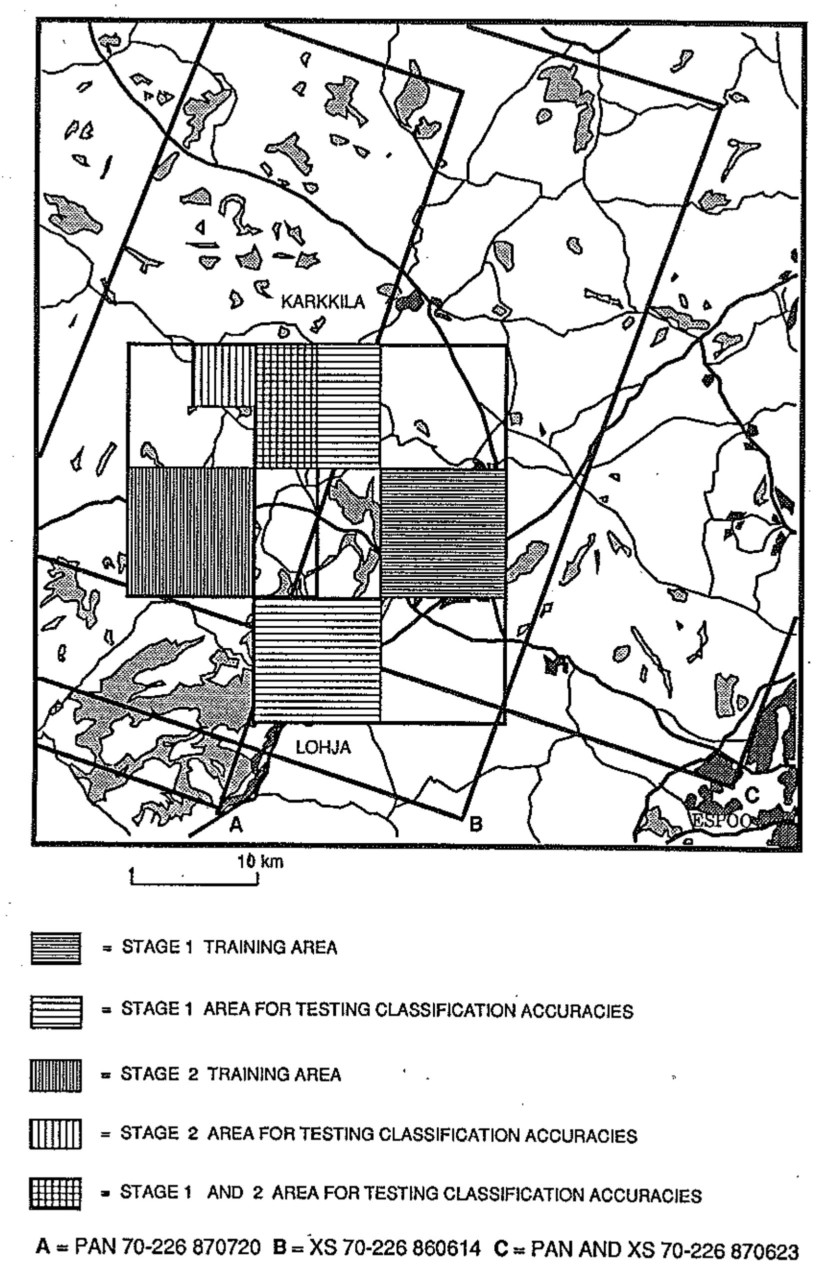
Konecny P., Lohmann P., Engel H. and G. Picht: The Use of SPOT Imagery on Analytical Photogrammetric Instruments. Proceedings on Symposium on SPOT 1 Image Utilization, Assessment, Results held in Paris November 1987, pp. 1173-1188.

Appendices



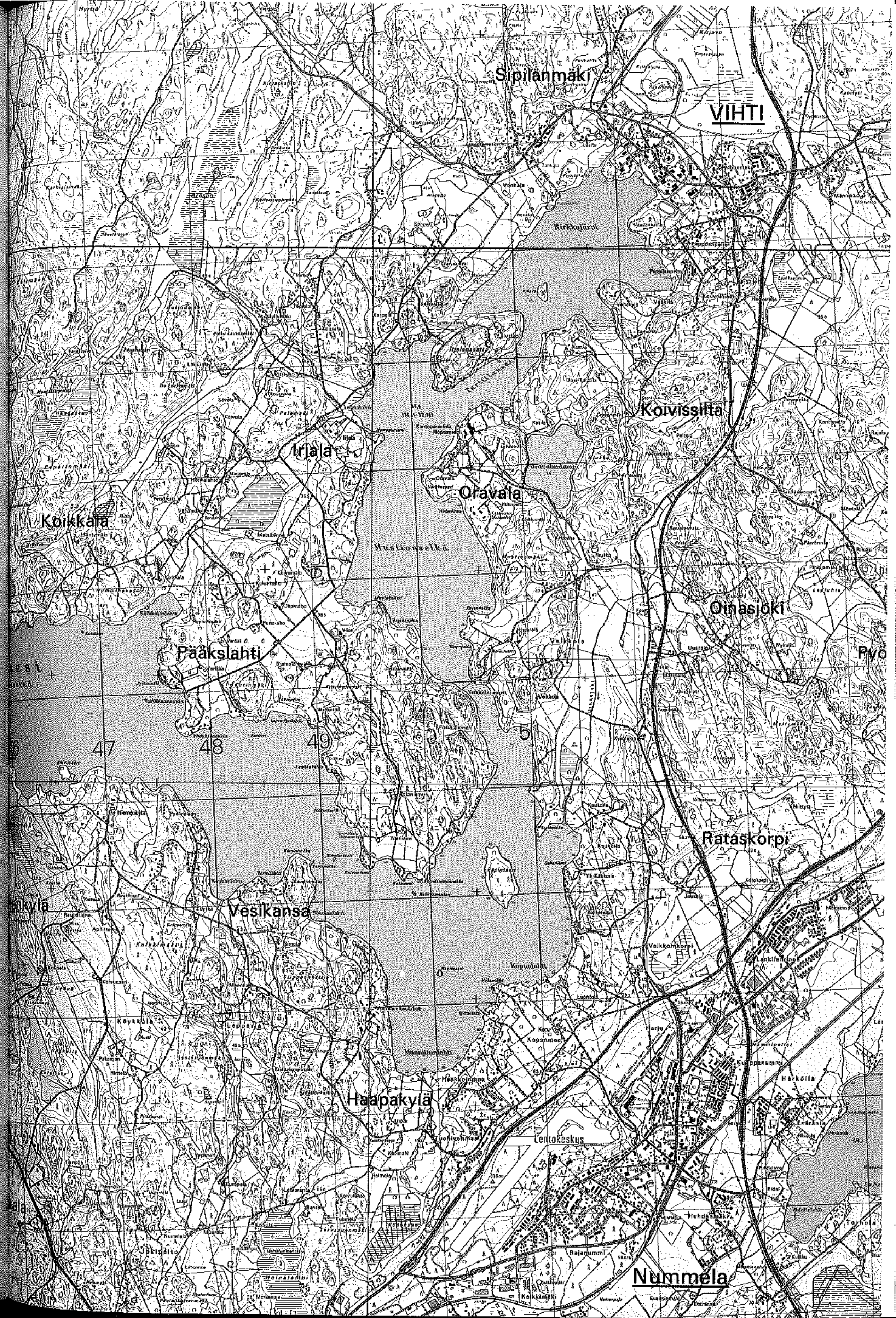
Location of investigated SPOT scenes A = Pan 70-226 870720, B = XS 70-226 860614, C = PAN and XS 70-226 870623. The scene B corresponds to the area of SPOT GRS 70-226. In requesting a panchromatic stereopair this area was specified. It can be seen, that there were problems in the registration of off-nadir view images from the wanted area.



Location of test areas.

Extract of the topographical map of 1:50000 covering the first test area. The extract covers the training area. ©Maanmittaushallitus (National Board of Survey of Finland), Helsinki 1990.

(see next page)


Sipilänmäki
VIHTI
Koivissilta
Irjala
Oravala
Koikkala
Oinasjoki
Pääkslahti
47
48
49
Rataskorpi
Vesikansa
Haapakylä
Lentokeskus
Nummela

		XS CH 1		XS CH 2		XS CH 3		
CLASS	AREA	MEAN	SD	MEAN	SD	MEAN	SD	HA
WATER	1	26.2	2.7	16.8	2.8	13.5	10.4	60093
	2	26.8	1.7	18.2	1.8	11.9	8.1	17148
	3	25.8	2.0	15.6	2.3	12.6	9.2	18950
	4	23.8	3.3	13.7	3.0	20.5	14.7	1217
FIELD	1	40.1	8.3	29.1	9.9	79.0	18.9	155728
	2	38.5	7.1	27.9	9.1	76.8	18.3	22995
	3	39.8	6.8	28.7	8.6	79.1	16.1	18920
	4	42.4	7.6	30.7	9.5	80.5	17.2	30378
OTHER	1	29.2	6.7	18.4	6.8	55.3	17.6	384178
	2	29.8	6.2	19.2	7.3	57.2	16.0	59857
	3	31.1	8.0	20.6	9.1	55.7	17.2	62131
	4	29.5	4.1	17.7	4.3	56.4	14.8	68405

Grey value distribution on the SPOT XS registrated on the 14th of June, 1986. The digital number means and standard deviations were calculated comparing Basic map water and field masks pixel by pixel with the original image. Areas (appendix 2): 1. Whole test area, 2. Training area, 3. Reference area A, 4. Reference area B.

INSTRUCTIONS FOR THE OEEPE TEST "INTERPRETATION OF SPOT IMAGERY"

1 AIMS

The aim of the test is to determine the best use of different types of SPOT imagery in topographic interpretation, however, without tying it down to any particular mapping scale or method. In the first place, the quality of interpretation and its geometric accuracy are to be determined. In the second place, a comparison is made of the time consumed using different methods.

2 THE AREA

The test area is 20 km x 30 km and is located in Southern Finland near the city of Lohja. As to its land use classification, the area is versatile (fields, different types of forests, waterways, marshes, roads and densely populated areas). As to its topography, it contains small-scale variations (z = 30...145 m).

3 MATERIAL

The digital image 70-226, corrected to the level 1B, has been processed at the National Board of Survey of Finland (NBS). The image is a little larger than the test area. The south-east corner of the image is missing due to the limitation of the original SPOT scene.

Details of the raster format are given on a separate paper.

Linear contrast stretching was used in film making. The image on the film is unrectified. The scale is 1:200 000.

The paper print is approximately in the scale 1:50 000.

Each participant may further process the images needed using the material delivered. The types and processing methods of the images used in the final interpretation are to be indicated in connection with reporting the results.

The digital elevation model (DEM) has been created by digitizing the contour line element (equidistance 5 m) of the Basic Map of Finland. More details about the DEM are given on a separate paper for those who have ordered the digital elevation model.

As an aid in interpretation, a complete interpretation of an area of 10 km x 10 km is given in the form of a Basic Map 1:20 000. Each participant will choose a necessary number of training areas from the map given. Also the legend of the Basic Map is given to the participants.

4 INTERPRETATION

The choice of the method and instrumentation is free. The interpretation is performed primarily in accordance with the given land use classes. However, the participant has the option of combining the classes or dividing them into subclasses and of leaving some classes uninterpreted.

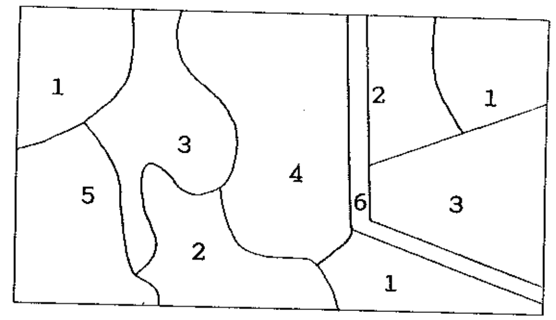
Classes and the alternatives for dividing them into subclasses:

- waterways
- fields
- forests --- deciduous forests
  coniferous forests ---- spruce forests
  pine forests
- felled forests
- young growing forests
- marshes
- bare rock
- gravel pits
- roads (possibly subclasses)
- settlements

5 RESULTS

The interpretation results will be presented either graphically (in the scale 1:50 000) or digitally in the ground coordinate system. The digital results can be in raster and vector form. Raster and vector formats are on separate papers. Pixel size after rectification should be 20 m x 20 m.

The graphic interpretation result should be on two separate sheets of plastic drawing material: a class boundary drawing on one sheet and corresponding class codes (numbers) on the other sheet. When the two sheets are put together each class number is inside one area. Roads are areas, too, though narrow ones. Naturally a list is needed about class codes and corresponding class names.



6 QUESTIONS ABOUT THE INTERPRETATION

The following questions are part of what we would like to know about the interpretation process. After you have answered these questions, please feel free to explain more, because at the conclusion stage every little piece of information may be of great value.

1. Image rectified before or after classification ?
2. Rectified using nearest neighbour, bilinear or cubic convolution resampling ?
3. Control point residuals in rectification (in pixels x, y) ?
4. Mean square error x, y, xy ?
5. Method used in control point measurements ?
6. Expected correctness of interpretation for each class (% correct) ?
7. Detailed description of the interpretation process ?
   - classification method: min. distance, max. likelihood etc.
   - number of training areas for each class
8. Have you interpreted many subclasses and merged them in the final interpretation result ?
9. Time consumed by the work ?
   - personnel resources
   - computer time (CPU)
10. General description of the system ?
    - production system or R&D system
    - software used

7 EVALUATION OF RESULTS

The pilot center (Finnish Geodetic Institute) will draft a conclusion. The evaluation will be based on Basic Maps 1:20 000 of the area, which will be corrected using the information available. In performing the evaluation, the methods will be grouped e.g. in accordance with the type of image and the method (visual/digital) used. An effort will be made to distinguish the production systems from R&D systems.

In the evaluation, attention will be paid to the following:

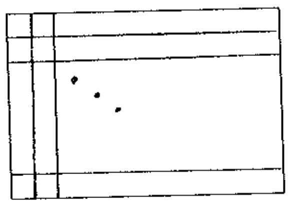
- correctness of classification
- geometric accuracy of pattern boundaries

The correctness of interpretation will be established by comparing the true classification (Basic Map) pattern by pattern or pixel by pixel with the classification interpreted. The classifications will be summed up in a 2-dimensional matrix, the elements of which correspond to all combinations of the true classification and the interpreted classification + the unclassified.

true class

interpreted class

unclassified



Using the matrix the correlations between classes are computed.

The comparison of geometric accuracy is performed in absolute form, as compared with true ground coordinates, and relatively, in which case the local errors of the transformation parameters are corrected before comparison. For small patterns, the comparison is performed only absolutely.

The accuracy of the pattern boundaries is determined by sampling, defining at regular intervals the distance between the true and interpreted boundaries. The results will be grouped in accordance with the classes on both sides of the boundary. If the interpreted pattern consists of several true patterns, it is compared with the corresponding pattern consisting of several patterns.

8 TIME TABLE

Delivery of a multispectral image to participants	May 1987
Interpretation of the multispectral image ->	December 31, 1987
Stereoscopic acquisition of multispectral and panchromatic images	summer 1987
Delivery of new material	November 1987
Interpretation of new material	--> May 31, 1988
Final report	May 1989

Instructions for the OEEPE Comm. E test "Interpretation of SPOT Imagery"

Second stage

1 PURPOSE

The purpose of this test is to evaluate the interpretability of panchromatic SPOT scenes.

2 AREA

The area of interest is 15 km x 20 km and it is located in southern Finland. Its corner coordinates are:

Gauss-Krüger

min north = 6690 000 m, max north = 6710 000 m
min east = 2490 000 m, max east = 2505 000 m

ED50 latitude and longitude (degrees, minutes, seconds)

min lat. = 60 19 17.0204, max lat. = 60 30 3.5506
min long. = 23 49 0.2168, max long. = 24 5 19.1514

3 MATERIAL

One panchromatic stereo pair is available (levels 1A and 1B). Scenes were taken on 23 June and 20 July 1987. Looking angles are 10.0 degrees east and 9.7 degrees west respectively.

One Basic Map 1:20 000 is an interpretation key. Also a legend of the Basic Map and false colour aerial photographs 1:31 000 are given to the participants. These photographs have been taken on 5 July 1987.

4 INTERPRETATION

The method and instrumentation of interpretation is free. Interpreted classes can be e.g.

- roads
- fields
- clearings
- marsh
- waters (lakes, rivers)

- forests
- built-up areas (settlements)

However, the participant has the option of combining the classes or dividing them into subclasses and of leaving some classes uninterpreted.

5 RESULTS

The interpretation results will be presented either graphically (on the scale 1:50 000) or digitally. The digital result should be in raster form. If a participant insists of delivering his result in vector form, he should contact the Finnish Geodetic Institute in advance for deciding the suitable format.

The graphic interpretation result should be on two separate sheets of plastic drawing material: a class boundary drawing on one sheet and corresponding class codes (numbers) on the other sheet.

Each participant will in detail describe the interpretation process he has used and will report the time consumed by the work (hours) as well as the personnel resources.

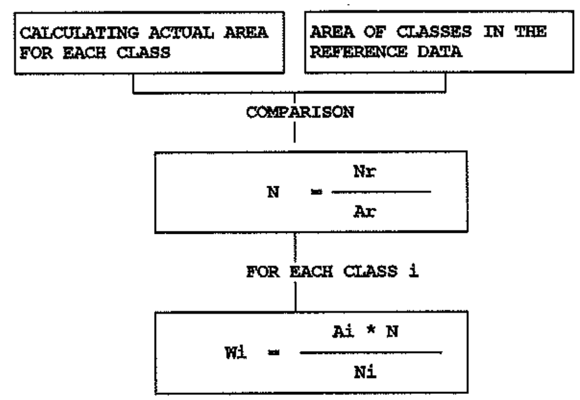
6 EVALUATION OF RESULTS

The Finnish Geodetic Institute will draft a conclusion. In the evaluation attention will be paid to the correctness of the classification.

7 TIME TABLE

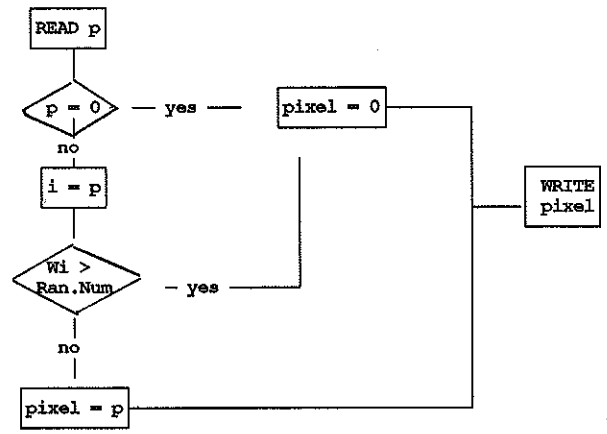
We expect that this second stage will be done before February 28, 1989.

(A)



Where:
N = total number of pixels in the sampled reference data
Nr = number of pixels in the most under-represented class
Ni = number of pixels in class i
Ar = actual area of the most under-represented class
Ai = actual area of class i
Wi = reduction coefficient for class i (0 < Wi <= 1)

(B)



Where: p = pixel in the original ref.data, pixel = pixel in the samplied ref.data

Scheme for area weighted sampling. Reduction of pixels was made by calculating a reduction coefficient for each class in the reference data. The value of the coefficient was inversly proportional to the over-representation of a class compared with the most under-represented class (A). The reference data sampling was made by using the coefficient and a pseudo random number generator (B).

ERROR MATRICES AND ACCURACY ESTIMATES OF INTERPRETATION OF GL 1 (XS-data)

1. ERROR MATRIX GL1 : TESTING WITHOUT FEATURE BOUNDARIES IN THE REFERENCE DATA

	REFERENCE CLASSES									
CLAS.	1	2	3	4	5	6	7	8	9	total
1	5922	0	0	0	0	0	0	0	0	5922
2	2	11034	17	59	10	32	388	7	761	12310
3	0	0	1861	859	446	0	45	21	52	3284
4	0	0	201	3297	165	0	0	0	0	3663
5	1	2	926	3137	633	215	204	45	154	5317
6	0	7	0	17	24	81	35	0	2	166
7	3	425	11	46	11	3	1137	8	80	1724
8	26	0	236	46	2	0	0	8	1	319
9	59	88	552	342	79	61	749	79	417	2426
tot	6013	11556	3804	7803	1370	392	2558	168	1467	35131

1 = WATERS 2 = FIELDS 3 = PINE FORESTS 4 = SPRUCE FORESTS 5 = MIXED FORESTS
6 = DECIDUOUS FORESTS 7 = SAPLING STANDS 8 = MARSHES 9 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA (int.)	AREA (count.)
1	100.0	98.5	99.2	1.000	0.000000	9.4	10.1
2	89.6	95.5	92.5	0.846	0.000015	35.3	24.7
3	56.7	48.9	52.5	0.514	0.000086	7.3	11.7
4	90.0	42.3	57.5	0.872	0.000040	5.4	24.0
5	11.9	46.2	18.9	0.083	0.000016	22.1	6.1
6	48.8	20.6	29.0	0.482	0.001532	1.0	2.9
7	66.0	44.4	53.1	0.632	0.000146	5.9	10.0
8	2.5	4.8	3.3	0.020	0.000076	0.6	0.7
9	17.2	28.4	21.4	0.136	0.000057	12.9	7.8

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 69.4 +/- 0.482
KAPPA = 0.623 +/- 0.0000151
VARIANCE OF KAPPA = 0.0000077215

2. ERROR MATRIX GL1 : TESTING WITH FEATURE BOUNDARIES IN THE REFERENCE DATA

CLAS.	REFERENCE CLASSES 1	2	3	4	5	6	7	8	9	total
1	6743	0	1	10	0	2	1	8	6	6771
2	27	16476	179	600	160	273	970	65	3777	22527
3	14	15	3072	1712	899	6	324	39	95	6176
4	14	5	458	5078	452	29	61	5	6	6108
5	66	146	2508	7723	2086	1105	1262	93	363	15352
6	2	32	6	81	89	230	148	5	4	597
7	15	729	141	378	113	83	2170	42	235	3906
8	123	0	294	108	13	5	4	46	4	597
9	293	409	1577	1456	532	332	2171	175	1112	8057
tot	7297	17812	8236	17146	4344	2065	7111	478	5602	70091

1 = WATERS 2 = FIELDS 3 = PINE FORESTS 4 = SPRUCE FORESTS 5 = MIXED FORESTS 6 = DECIDUOUS FORESTS 7 = SAPLING STANDS 8 = MARSHES 9 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	99.6	92.4	95.9	0.995	0.000001	9.4	10.1
2	73.1	92.5	81.7	0.640	0.000013	35.3	24.7
3	49.7	37.3	42.6	0.430	0.000047	7.3	11.7
4	83.1	29.6	43.7	0.777	0.000039	5.3	24.0
5	13.6	48.0	21.2	0.079	0.000006	22.2	6.1
6	38.5	11.1	17.3	0.367	0.000417	1.0	2.9
7	55.6	30.5	39.4	0.505	0.000074	5.9	10.0
8	7.7	9.6	8.6	0.071	0.000119	0.6	0.7
9	13.8	19.9	16.3	0.063	0.000015	12.9	7.8

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 52.8 +/- 0.370
KAPPA = 0.443 +/- 0.0000086
VARIANCE OF KAPPA = 0.0000043687

3. ERROR MATRIX GL1: TESTING WITHOUT FEATURE BOUNDARIES IN THE REFERENCE DATA OPTIMIZED CLASSIFICATION

CLAS.	REFERENCE CLASSES 1	2	3	4	total
1	5922	0	0	0	5922
2	2	11140	506	662	12310
3	30	472	13849	122	14473
4	59	91	1985	291	2426
tot	6013	11703	16340	1075	35131

1 = WATERS 2 = FIELDS 3 = FORESTS/SAPLING STANDS/CLEARING/WOODED MARSH 4 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	100.0	98.5	99.2	1.000	0.000000	9.4	10.1
2	90.5	95.2	92.8	0.857	0.000014	35.2	25.6
3	95.7	84.8	89.9	0.919	0.000009	41.7	55.5
4	12.0	27.1	16.6	0.092	0.000041	13.5	7.1

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 88.8 +/- 0.330
KAPPA = 0.831 +/- 0.0000121
VARIANCE OF KAPPA = 0.0000061720

APPENDIX 8.2

ERROR MATRICES AND ACCURACY ESTIMATES OF INTERPRETATION OF IFAG

A = original interpretation
B = interpretation mode filtered by the pilot centre

1.A ERROR MATRIX : TESTING WITHOUT FEATURE BOUNDARIES IN THE REFERENCE DATA

	REFERENCE CLASSES				
CLAS.	1	2	3	4	total
1	5780	0	0	0	5780
2	5	9938	380	1546	11869
3	118	337	12473	1842	14770
4	110	1281	516	805	2712
tot	6013	11556	13369	4193	35131

1 = WATER 2 = AGRICULTURAL AREA 3 = ALL FORESTS 4 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	100.0	96.1	98.0	1.000	0.000000	8.8	10.1
2	83.7	86.0	84.9	0.758	0.000022	33.7	24.7
3	84.4	93.3	88.7	0.749	0.000019	48.1	44.7
4	29.7	19.2	23.3	0.202	0.000089	9.5	20.5

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 82.5 +/- 0.397
KAPPA = 0.747 +/- 0.0000157
VARIANCE OF KAPPA = 0.0000080191

APPENDIX 8.2 (continued)

1.B ERROR MATRIX: TESTING WITHOUT FEATURE BOUNDARIES IN THE REFERENCE DATA

	REFERENCE CLASSES				
CLAS.	1	2	3	4	total
1	5841	0	0	0	5841
2	2	10366	280	1513	12161
3	83	314	12769	1941	15107
4	87	876	320	739	2022
tot	6013	11556	13369	4193	35131

1 = WATER 2 = AGRICULTURAL AREA 3 = FOREST 4 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	100.0	97.1	98.5	1.000	0.000000	9.0	10.1
2	85.2	89.7	87.4	0.780	0.000020	33.4	24.7
3	84.5	95.5	89.7	0.750	0.000019	50.6	44.7
4	36.5	17.6	23.8	0.279	0.000138	7.0	20.5

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 84.6 +/- 0.378
KAPPA = 0.776 +/- 0.0000144
VARIANCE OF KAPPA = 0.0000073313

2.A ERROR MATRIX: TESTING WITH FEATURE BOUNDARIES IN THE REFERENCE DATA

CLAS.	REFERENCE CLASSES 1	2	3	4	total
1	6376	0	3	5	6384
2	30	14716	1817	5333	21896
3	637	1080	28173	5619	35509
4	247	2011	1778	2207	6243
tot	7290	17807	31771	13164	70032

1 = WATER 2 = AGRICULTURAL AREA 3 = FOREST 4 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	99.9	87.5	93.2	0.999	0.000000	8.8	10.1
2	67.2	82.6	74.1	0.560	0.000014	33.7	24.7
3	79.3	88.7	83.7	0.622	0.000011	48.1	44.7
4	35.4	16.8	22.7	0.204	0.000050	9.5	20.5

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 73.5 +/- 0.327
KAPPA = 0.601 +/- 0.0000113
VARIANCE OF KAPPA = 0.0000057735

2.B ERROR MATRIX: TESTING WITH FEATURE BOUNDARIES IN THE REFERENCE DATA

CLAS.	REFERENCE CLASSES 1	2	3	4	total
1	6499	0	3	4	6506
2	22	15289	1334	5245	21890
3	559	1131	29373	6062	37125
4	210	1387	1061	1853	4511
tot	7290	17807	31771	13164	70032

1 = WATER 2 = AGRICULTURAL AREA 3 = FOREST 4 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	99.9	89.2	94.2	0.999	0.000000	9.0	10.1
2	69.8	85.9	77.0	0.596	0.000014	33.4	24.7
3	79.1	92.5	85.3	0.618	0.000011	50.6	44.7
4	41.1	14.1	21.0	0.274	0.000076	7.0	20.5

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 75.7 +/- 0.318
KAPPA = 0.631 +/- 0.0000107
VARIANCE OF KAPPA = 0.0000054792

3.A ERROR MATRIX: TESTING WITHOUT FEATURE BOUNDARIES IN THE REFERENCE DATA OPTIMIZED CLASSIFICATION

CLAS.	REFERENCE CLASSES 1	2	3	4	total
1	5855	0	1	5	5861
2	5	9938	1224	702	11869
3	43	337	14071	238	14689
4	110	1281	1044	277	2712
tot	6013	11556	16340	1222	35131

1 = WATER 2 = AGRICULTURAL AREA 3 = FOREST/SAPLING STAND/CLEARING/FORESTED MARSH 4 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	99.9	97.4	98.6	0.999	0.000000	9.2	10.1
2	83.7	86.0	84.9	0.758	0.000022	33.7	25.6
3	95.8	86.1	90.7	0.921	0.000009	50.4	55.5
4	10.2	22.7	14.1	0.070	0.000032	7.0	8.8

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 85.8 +/- 0.365
KAPPA = 0.786 +/- 0.0000146
VARIANCE OF KAPPA = 0.0000074402

3.B ERROR MATRIX: TESTING WITHOUT FEATURE BOUNDARIES IN THE REFERENCE DATA OPTIMIZED CLASSIFICATION

CLAS.	REFERENCE CLASSES 1	2	3	4	total
1	5871	0	0	4	5875
2	2	10366	1087	706	12161
3	53	314	14477	229	15073
4	87	876	776	283	2022
tot	6013	11556	16340	1222	35131

1 = WATER 2 = AGRICULTURAL AREA 3 = FOREST/SAPLING STAND/CLEARING/FOREST 4 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	99.9	97.6	98.8	0.999	0.000000	9.2	10.1
2	85.2	89.7	87.4	0.780	0.000020	33.7	25.6
3	96.0	88.6	92.2	0.926	0.000008	50.4	55.5
4	14.0	23.2	17.4	0.108	0.000058	7.0	8.8

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 88.2 +/- 0.337
KAPPA = 0.821 +/- 0.0000128
VARIANCE OF KAPPA = 0.0000065517

APPENDIX 8.3

ERROR MATRICES AND ACCURACY ESTIMATES OF INTERPRETATION OF IGN1 (XS-DATA)

1. ERROR MATRIX : TESTING WITHOUT FEATURE BOUNDARIES IN THE REFERENCE DATA

	REFERENCE CLASSES							
CLAS.	1	2	3	4	5	6	7	total
1	5976	246	37	8	2	11	0	6280
2	7	10265	171	329	0	92	5	10869
3	8	212	13031	1424	83	3	7	14768
4	0	53	117	777	0	0	1	948
5	3	84	134	0	77	0	0	298
6	1	452	140	15	0	651	16	1275
7	0	71	10	0	0	7	98	186
tot	5995	11383	13640	2553	162	764	127	34624

1 = water 2 = field/meadow 3 = all forests 4 = sapling stand 5 = all marshes
6 = built up area 7 = quarry

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	95.1	99.7	97.4	0.941	0.000011	11.2	10.1
2	94.4	90.2	92.3	0.917	0.000010	27.7	25.6
3	88.2	95.5	91.7	0.806	0.000017	46.9	44.7
4	82.0	30.4	44.4	0.805	0.000180	3.2	10.0
5	25.8	47.5	33.5	0.255	0.000641	0.4	1.5
6	51.1	85.2	63.9	0.500	0.000198	6.6	5.5
7	52.7	77.2	62.6	0.525	0.001343	0.5	0.5

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 89.2+/- 0.327
KAPPA = 0.844 +/- 0.0000108
VARIANCE OF KAPPA = 0.0000054986

2. ERROR MATRIX IGN1: TESTING WITH FEATURE BOUNDARIES IN THE REFERENCE DATA

	REFERENCE CLASSES							
CLAS.	1	2	3	4	5	6	7	total
1	7072	382	237	25	24	42	0	7782
2	51	14748	1653	870	17	452	15	17806
3	112	1178	28080	4698	270	215	35	34588
4	6	140	713	1368	1	58	7	2293
5	18	121	199	3	146	0	0	487
6	13	1125	614	80	0	2761	80	4673
7	0	129	59	6	0	98	205	497
tot	7272	17823	31555	7050	458	3626	342	68126

1 = water 2 = field/meadow 3 = forest 4 = sapling stand 5 = marshes 6 = built up area 7 = quarry

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	90.9	97.3	94.0	0.898	0.000013	11.2	10.1
2	82.8	82.7	82.8	0.767	0.000013	27.7	25.6
3	81.2	89.0	84.9	0.649	0.000011	46.9	45.5
4	59.7	19.4	29.3	0.550	0.000127	3.2	10.0
5	30.0	31.9	30.9	0.295	0.000433	0.4	1.5
6	59.1	76.1	66.5	0.568	0.000054	6.6	5.5
7	41.2	59.9	48.9	0.410	0.000488	0.5	0.5

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 79.8 +/- 0.301
KAPPA = 0.702 +/- 0.0000096
VARIANCE OF KAPPA = 0.0000049002

2. ERROR MATRIX LMV1 : TESTING WITH FEATURE BOUNDARIES IN THE REFERENCE DATA

CLAS.	REFERENCE CLASSES								total
	1	2	3	4	5	6	7	8	
1	6999	15	26	5	3	23	15	0	7086
2	13	15487	922	226	265	26	324	23	17286
3	109	107	16654	257	532	101	60	5	17825
4	18	220	3399	1148	740	153	64	9	5751
5	34	1321	1299	204	3206	112	96	11	6283
6	93	332	6986	211	2302	645	77	35	10681
7	31	694	126	0	0	0	3067	23	3941
8	0	61	34	0	1	0	28	247	371
tot	7297	18237	29446	2051	7049	1060	3731	353	69224

1 = water 2 = field/meadow 3 = coniferous forest 4 = deciduous forest 5 = sapling stand/felled forest 6 = marshes 7 = built-up areas 8 = quarry

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	98.8	95.9	97.3	0.986	0.000002	10.1	10.1
2	89.6	84.9	87.2	0.859	0.000009	26.9	25.6
3	93.4	56.6	70.5	0.886	0.000010	21.2	41.8
4	20.0	56.0	29.4	0.175	0.000026	8.6	2.9
5	51.0	45.5	48.1	0.455	0.000045	10.0	10.0
6	6.0	60.8	11.0	0.046	0.000004	14.6	1.5
7	77.8	82.2	80.0	0.766	0.000048	6.7	5.5
8	66.6	70.0	68.2	0.664	0.000604	0.4	0.5

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 68.6 +/- 0.346
KAPPA = 0.605 +/- 0.0000088
VARIANCE OF KAPPA = 0.0000045022

3. ERROR MATRIX LMV1 : TESTING WITHOUT FEATURE BOUNDARIES IN THE REFERENCE DATA OPTIMIZED CLASSIFICATION

CLAS.	REFERENCE CLASSES						total
	1	2	3	4	5	6	
1	5973	1	15	0	0	2	5991
2	3	10722	157	47	8	1	10938
3	29	575	16057	3	5	165	16834
4	8	285	20	681	6	0	1000
5	0	27	9	7	108	0	151
tot	6013	11610	16258	738	127	168	34914

1 = water 2 = field/meadow 3 = forest/sapling stand/felled forest/forested marsh 4 = built-up areas 5 = quarry 6 = other

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	99.7	99.3	99.5	0.996	0.000001	10.1	10.1
2	98.0	92.3	95.1	0.970	0.000004	26.9	25.6
3	95.4	98.8	97.0	0.913	0.000009	54.4	55.5
4	68.1	92.3	78.4	0.674	0.000223	6.7	5.5
5	71.5	85.0	77.7	0.714	0.001355	0.4	0.5

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 96.1 +/- 0.204
KAPPA = 0.939 +/- 0.0000051
VARIANCE OF KAPPA = 0.0000026100

APPENDIX 8.5

ERROR MATRICES AND ACCURACY ESTIMATES OF INTERPRETATION OF GL2 (P-STEREO PAIR)

1. ERROR MATRIX GL2 : TESTING WITHOUT FEATURE BOUNDARIES IN THE REFERENCE DATA

	REFERENCE CLASSES							
CLAS.	1	2	3	4	5	6	7	total
1	15700	0	174	39	0	0	0	15913
2	2	66967	153	1351	263	15	0	68751
3	251	2538	64363	15186	461	20	890	83709
4	0	398	1177	3272	6	1	298	5152
5	0	33	3	0	400	0	0	436
6	0	0	10	23	6	556	0	595
7	0	0	9	25	0	0	4	38
tot	15953	69936	65889	19896	1136	592	1192	174594

1 = WATER 2 = FIELD/MEADOW 3 = FOREST 4 = SAPLING STAND/CLEARING 5 = BUILT UP AREA 6 = QUARRY 7 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	98.7	98.4	98.5	0.985	0.000001	3.3	7.3
2	97.4	95.8	96.6	0.957	0.000001	31.2	35.0
3	76.9	97.9	86.0	0.629	0.000004	60.0	39.5
4	63.5	16.4	26.1	0.588	0.000056	4.5	13.5
5	91.7	35.2	50.9	0.917	0.000176	0.5	2.7
6	93.4	93.9	93.7	0.934	0.000104	0.3	0.5
7	10.5	0.3	0.7	0.099	0.002512	0.4	1.5

ALL CLASSES (95 % confidence level)

TOTAL ACCURACY = 86.6 +/- 0.160
KAPPA = 0.794 +/- 0.0000028
VARIANCE OF KAPPA = 0.0000014320

APPENDIX 8.5 (continued)

2. ERROR MATRIX GL2 : TESTING WITH FEATURE BOUNDARIES IN THE REFERENCE DATA

	REFERENCE CLASSES							
CLAS.	1	2	3	4	5	6	7	total
1	17704	13	512	112	5	12	27	18385
2	3471	115078	3456	3532	3181	94	52	128864
3	5803	12722	138950	38654	4821	346	4385	205681
4	107	1755	3405	7695	109	41	452	13564
5	57	590	136	12	1896	0	0	2691
6	0	23	151	141	107	1150	0	1572
7	94	1	54	99	0	0	543	791
tot	27236	130182	146664	50245	10119	1643	5459	371548

1 = WATER 2 = FIELD/MEADOW 3 = FOREST 4 = SAPLING STAND/CLEARING 5 = BUILT UP AREA 6 = QUARRY 7 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	96.3	65.0	77.6	0.960	0.000002	3.3	7.3
2	89.3	88.4	88.8	0.835	0.000002	31.2	35.0
3	67.6	94.7	78.9	0.464	0.000002	60.0	39.4
4	56.7	15.3	24.2	0.500	0.000023	4.5	13.5
5	70.5	18.7	29.6	0.696	0.000081	0.5	2.7
6	73.2	70.0	71.5	0.730	0.000126	0.3	0.5
7	68.6	9.9	17.4	0.682	0.000280	0.4	1.5

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 76.2 +/- 0.137
KAPPA = 0.634 +/- 0.0000020
VARIANCE OF KAPPA = 0.0000010162

3. ERROR MATRIX: TESTING WITHOUT FEATURE BOUNDARIES IN THE REFERENCE DATA OPTIMIZED CLASSIFICATION

	REFERENCE CLASSES						
CLAS.	1	2	3	4	5	6	total
1	15700	0	213	0	0	0	15913
2	2	66967	1504	263	15	0	68751
3	251	2936	85011	467	21	179	88865
4	0	33	3	400	0	0	436
5	0	0	33	6	556	0	595
tot	15953	69936	86764	1136	592	179	174560

1 = WATER 2 = FIELD/MEADOW 3 = FOREST/SAPLING STAND/CLEARING/WOODED MARSH 4 = BUILT UP AREA 5 = QUARRY 6 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	98.7	98.4	98.5	0.985	0.000001	3.3	7.3
2	97.4	95.8	96.6	0.957	0.000001	31.2	35.0
3	95.7	98.0	96.8	0.914	0.000002	64.6	54.0
4	91.7	35.2	50.9	0.917	0.000176	0.5	2.7
5	93.4	93.9	93.7	0.934	0.000104	0.3	0.5

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 96.6 +/- 0.085
KAPPA = 0.942 +/- 0.0000011
VARIANCE OF KAPPA = 0.0000005577

ERROR MATRICES AND ACCURACY ESTIMATES OF INTERPRETATION OF GL 3 (XS/P-DATA)

1. ERROR MATRIX: TESTING WITHOUT FEATURE BOUNDARIES IN THE REFERENCE DATA

	REFERENCE CLASSES					
CLAS.	1	2	3	4	5	total
1	15810	0	19	0	0	15829
2	82	63386	671	113	993	65245
3	27	738	54340	35	9226	64366
4	3	1753	71	717	0	2544
5	31	4059	10788	271	11461	26610
tot	15953	69936	65889	1136	21680	174594

1 = WATER 2 = FIELD/MEADOW 3 = FOREST 4 = BUILT UP AREA 5 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	99.9	99.1	99.5	0.999	0.000000	3.5	7.3
2	97.2	90.6	93.8	0.952	0.000001	31.5	35.0
3	84.4	82.5	83.4	0.750	0.000005	44.0	39.5
4	28.2	63.1	39.0	0.277	0.000079	2.1	2.7
5	43.1	52.9	47.5	0.350	0.000010	19.2	15.4

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 83.5 +/- 0.174
KAPPA = 0.758 +/- 0.0000031
VARIANCE OF KAPPA = 0.0000016020

APPENDIX 8.6 (continued)

2. ERROR MATRIX GL3 : TESTING WITH FEATURE BOUNDARIES IN THE REFERENCE DATA

CLAS.	REFERENCE CLASSES 1	2	3	4	5	total
1	18036	9	481	32	122	18680
2	3975	108375	7467	3056	3407	126280
3	3345	5178	109977	1263	27325	147088
4	262	5498	676	3813	6	10255
5	1618	11122	28063	1955	26487	69245
tot	27236	130182	146664	10119	57347	371548

1 = WATER 2 = FIELD/MEADOW 3 = FOREST 4 = BUILT UP AREA 5 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	96.6	66.2	78.6	0.963	0.000002	3.5	7.3
2	85.8	83.2	84.5	0.782	0.000002	31.4	35.0
3	74.8	75.0	74.9	0.583	0.000003	44.0	39.5
4	37.2	37.7	37.4	0.354	0.000023	2.1	2.7
5	38.3	46.2	41.8	0.270	0.000004	19.2	15.4

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 71.8 +/- 0.145
KAPPA = 0.592 +/- 0.0000021
VARIANCE OF KAPPA = 0.0000010694

3. ERROR MATRIX: OPTIMIZED CLASSIFICATION NOT REALIZED

APPENDIX 8.7

ERROR MATRICES AND ACCURACY ESTIMATES OF INTERPRETATION OF IGN2 (P-STEREO PAIR)

1. ERROR MATRIX IGN2: TESTING WITHOUT FEATURE BOUNDARIES IN THE REFERENCE DATA

CLAS.	REFERENCE CLASSES 1	2	3	4	5	6	7	total
1	15819	159	160	11	0	0	3	16152
2	90	66593	1936	5170	146	280	150	74365
3	34	92	59635	5611	84	9	13	65478
4	0	951	4405	8711	2	0	13	14082
5	10	553	251	29	743	1	0	1587
6	0	86	14	0	88	278	0	466
7	0	3	5	147	0	14	0	169
tot	15953	68437	66406	19679	1063	582	179	172299

1 = WATER 2 = FIELD/MEADOW 3 = FOREST 4 = SAPLING STAND/CLEARING 5 = BUILT UP AREA 6 = QUARRY 7 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	97.9	99.2	98.5	0.977	0.000002	3.5	7.3
2	89.5	97.3	93.3	0.827	0.000003	35.2	35.0
3	91.1	89.8	90.4	0.855	0.000003	45.0	40.5
4	61.9	44.3	51.6	0.569	0.000020	9.9	13.5
5	46.8	69.9	56.1	0.465	0.000157	2.2	2.7
6	59.7	47.8	53.1	0.595	0.000519	0.3	0.4
7	0.0	0.0	0.0	-0.001	0.000000	0.8	0.4

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 88.1 +/- 0.153
KAPPA = 0.821 +/- 0.0000026
VARIANCE OF KAPPA = 0.0000013081

2. ERROR MATRIX: TESTING WITH FEATURE BOUNDARIES IN THE REFERENCE DATA

CLAS.	REFERENCE CLASSES 1	2	3	4	5	6	7	total
1	18181	1075	1067	140	95	0	72	20630
2	4212	113551	11288	11046	2618	555	570	143840
3	3817	2939	122491	19188	1577	159	828	150999
4	471	2589	11310	18250	324	6	164	33114
5	205	3404	1239	275	4162	75	0	9360
6	5	192	105	53	239	616	0	1210
7	4	50	74	287	0	74	0	489
tot	26895	123800	147574	49239	9015	1485	1634	359642

1 = WATER 2 = FIELD/MEADOW 3 = FOREST 4 = SAPLING STAND/CLEARING 5 = BUILT UP AREA 6 = QUARRY 7 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	88.1	67.6	76.5	0.872	0.000006	3.5	7.3
2	78.9	91.7	84.9	0.679	0.000002	35.2	35.0
3	81.1	83.0	82.1	0.680	0.000002	45.0	40.5
4	55.1	37.1	44.3	0.480	0.000009	9.9	13.5
5	44.5	46.2	45.3	0.430	0.000027	2.2	2.7
6	50.9	41.5	45.7	0.507	0.000208	0.3	0.4
7	0.0	0.0	0.0	-0.0	0.000000	0.8	0.4

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 77.1 +/- 0.137
KAPPA = 0.659 +/- 0.0000019
VARIANCE OF KAPPA = 0.0000009933

3. ERROR MATRIX IGN2 : TESTING WITHOUT FEATURE BOUNDARIES IN THE REFERENCE DATA OPTIMIZED CLASSIFICATION

CLAS.	REFERENCE CLASSES 1	2	3	4	5	6	total
1	15819	159	171	0	0	3	16152
2	90	66593	7106	146	280	150	74365
3	34	1046	78514	86	23	26	79729
4	10	553	280	743	1	0	1587
5	0	86	14	88	278	0	466
tot	15953	68437	86085	1063	582	179	172299

1 = WATER 2 = FIELD/MEADOW 3 = FOREST/SAPLING STAND/CLEARING/WOODED MARSH 4 = BUILT UP AREA 5 = QUARRY 6 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	97.9	99.2	98.54	0.977	0.000002	3.8	7.3
2	89.5	97.3	93.3	0.827	0.000003	35.2	35.0
3	98.5	91.2	94.7	0.970	0.000001	55.1	54.0
4	46.8	69.9	56.1	0.465	0.000157	2.2	2.7
5	59.7	47.8	53.1	0.595	0.000519	0.3	0.5

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 94.0 +/- 0.112
KAPPA = 0.898 +/- 0.0000019
VARIANCE OF KAPPA = 0.0000009465

ERROR MATRICES AND ACCURACY ESTIMATES OF INTERPRETATION OF LMV 2 (XS/P-DATA)

1.ERROR MATRIX : TESTING WITHOUT FEATURE BOUNDARIES IN THE REFERENCE DATA

CLAS.	REFERENCE CLASSES 1	2	3	4	5	6	7	total
1	15800	0	0	0	0	0	0	15800
2	0	66774	631	120	596	195	555	68871
3	67	29	56804	65	6664	10	121	63760
4	0	358	2368	405	819	7	2	3959
5	85	1449	5970	203	11698	169	93	19667
6	0	132	6	0	0	645	0	783
7	1	670	8	4	79	103	0	865
tot	15953	69412	65787	797	19856	1129	771	173705

1 = WATER 2 = FIELD/MEADOW 3 = CONIFEROUS FOREST 4 = DECIDUOUS FOREST
5 = YOUNG GROWING/FELLED FOREST 6 = BUILT UP AREA 7 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	100.0	99.0	99.5	1.000	0.000000	3.0	7.3
2	97.0	96.2	96.6	0.949	0.000001	32.6	35.0
3	89.1	86.3	87.7	0.824	0.000004	34.5	38.2
4	10.2	50.8	17.0	0.098	0.000022	8.0	2.3
5	59.5	58.9	59.2	0.543	0.000014	20.2	13.5
6	82.4	57.1	67.5	0.823	0.000188	0.5	2.7
7	0.0	0.0	0.0	-0.004	0.000000	0.9	0.7

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 87.6 +/- 0.155
KAPPA = 0.818 +/- 0.0000025
VARIANCE OF KAPPA = 0.0000012659

2. ERROR MATRIX LMV2 : TESTING WITH FEATURE BOUNDARIES IN THE REFERENCE DATA

CLAS.	REFERENCE CLASSES 1	2	3	4	5	6	7	total
1	17395	0	5	53	0	2	1	17456
2	3748	116966	3956	2108	1974	3063	1175	132990
3	3031	622	105736	1084	15589	460	1105	127627
4	863	1515	8160	2720	2807	406	26	16497
5	1973	6437	22797	2190	29149	2583	931	66060
6	52	829	122	6	1	2272	0	3282
7	96	1980	155	79	209	1022	11	3552
tot	27158	128349	140931	8240	49729	9808	3249	367464

1 = WATER 2 = FIELD/MEADOW 3 = CONIFEROUS FOREST 4 = DECIDUOUS FOREST
5 = YOUNG GROWING/FELLED FOREST 6 = BUILT UP AREA 7 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	99.7	64.1	78.0	0.996	0.000000	3.0	7.3
2	88.0	91.1	89.5	0.815	0.000002	32.8	35.0
3	82.8	75.0	78.7	0.722	0.000002	34.5	38.2
4	16.5	33.0	22.0	0.146	0.000008	8.0	2.2
5	44.1	58.6	50.3	0.354	0.000004	20.2	13.5
6	69.2	23.2	34.7	0.684	0.000068	0.5	2.7
7	0.3	0.3	0.3	-0.006	0.000001	0.9	0.7

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 74.6 +/- 0.141
KAPPA = 0.643 +/- 0.0000018
VARIANCE OF KAPPA = 0.0000009080

APPENDIX 8.8 (continued)

3. ERROR MATRIX LMV2 : TESTING WITHOUT FEATURE BOUNDARIES IN THE REFERENCE DATA OPTIMIZED CLASSIFICATION

CLAS.	REFERENCE CLASSES 1	2	3	4	5	total
1	15800	0	0	0	0	15800
2	1	67444	1438	298	555	69736
3	152	1836	84996	186	216	87386
4	0	132	6	645	0	783
tot	15953	69412	86440	1129	771	173705

1 = WATER 2 = FIELD/MEADOW 3 = FOREST/SAPLING STAND/CLERARING/WOODED MARSH 4 = BUILT UP AREA 5 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	100.0	99.0	99.5	1.000	0.000000	3.0	7.3
2	96.7	97.2	96.9	0.945	0.000001	33.1	35.0
3	97.3	98.3	97.8	0.946	0.000001	61.7	53.0
4	82.4	57.1	67.5	0.823	0.000188	0.5	2.7

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 97.2 +/- 0.077
KAPPA = 0.952 +/- 0.0000009
VARIANCE OF KAPPA = 0.000000458

APPENDIX 8.9

ERROR MATRICES AND ACCURACY ESTIMATES OF INTERPRETATION OF SKV (P-DATA)

1. ERROR MATRIX: TESTING WITHOUT FEATURE BOUNDARIES IN THE REFERENCE DATA

CLAS.	REFERENCE CLASSES 1	2	3	4	5	total
1	15830	94	50	2	0	15976
2	3	56953	747	2578	1185	61466
3	113	191	62874	9377	192	72747
4	7	11486	3035	7847	304	22679
5	0	697	0	0	211	908
tot	15953	69421	66706	19804	1892	173776

1 = WATER 2 = FIELD/MEADOW 3 = FOREST 4 = SAPLING STAND/CLEARING 5 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	99.1	99.2	99.2	0.990	0.000001	3.9	7.3
2	92.7	82.0	87.0	0.878	0.000003	27.5	35.0
3	86.4	94.3	90.2	0.780	0.000004	51.6	40.5
4	34.6	39.6	36.9	0.262	0.000011	16.7	13.5
5	23.2	11.2	15.1	0.224	0.000199	0.3	3.6

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 82.7 +/- 0.178
KAPPA = 0.744 +/- 0.0000033
VARIANCE OF KAPPA = 0.0000016750

2. ERROR MATRIX SKV: TESTING WITH FEATURE BOUNDARIES IN THE REFERENCE DATA

CLAS.	REFERENCE CLASSES 1	2	3	4	5	total
1	18533	852	685	21	156	20247
2	2517	96754	3301	6095	6486	115153
3	4510	3753	135004	25690	2915	171872
4	1555	24396	9694	17528	2416	55589
5	8	1056	6	21	357	1448
tot	27123	126811	148690	49355	12330	364309

1 = WATER 2 = FIELD/MEADOW 3 = FOREST 4 = CLEARING 5 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	91.5	68.3	78.2	0.909	0.000004	3.9	7.3
2	84.0	76.3	80.0	0.755	0.000002	27.5	35.0
3	78.5	90.8	84.2	0.638	0.000002	51.6	40.5
4	31.5	35.5	33.4	0.208	0.000004	16.7	13.5
5	24.7	2.9	5.2	0.220	0.000137	0.3	3.6

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 73.6 +/- 0.143
KAPPA = 0.608 +/- 0.0000020
VARIANCE OF KAPPA = 0.0000010377

3. ERROR MATRIX SKV : TESTING WITHOUT FEATURE BOUNDARIES IN THE REFERENCE DATA OPTIMIZED CLASSIFICATION

CLAS.	REFERENCE CLASSES 1	2	3	4	total
1	15830	94	52	0	15976
2	3	56953	3325	1185	61466
3	120	11677	83133	496	95426
4	0	697	86	211	994
tot	15953	69421	86596	1892	173862

1 = WATER 2 = FIELD/MEADOW 3 = FOREST/SAPLING STAND/CLEARING/WOODED MARSH 4 = OTHER

CLASS	OA	IA	MA	κ_i	$\sigma^2(\kappa_i)$	AREA	AREA
1	99.1	99.2	99.2	0.990	0.000001	3.8	7.3
2	92.7	82.0	87.0	0.878	0.000003	26.8	35.0
3	87.1	96.0	91.3	0.743	0.000004	66.4	54.0
4	21.2	11.2	14.6	0.204	0.000170	0.3	3.6

ALL CLASSES (95 % confidence limits)

TOTAL ACCURACY = 89.8+/- 0.142
KAPPA = 0.823 +/- 0.0000031
VARIANCE OF KAPPA = 0.0000015972

CONFUSION MATRIX OF INTERPRETATION OF GL1 (XS-data)

In this matrix all reference pixels (feature boundary pixels exepted) were tested. The proportional areas of the classes do not match with the actual areas covered by the same classes in the field. Thus accuracy estimates can not be calculated using this matrix

CONFUSION MATRIX OF INTERPRETATION OF GL 1 (XS-DATA)

REFERENCE CLASSES (without feature boundaries)

CLAS.	1	2	3	4	5	6	7	8	9	10	11	12	13	total
1	0	0	0	0	0	0	0	0	0	0	0	41413	0	41413
2	0	39	33	131	1	90	2	0	0	0	13	0	80	389
3	30	118	14	49	32	829	16	138	191	550	0	14	77456	79437
4	398	6029	338	1	0	5	0	0	0	0	0	0	0	6771
5	3417	1632	817	0	14	80	43	0	0	0	188	9	0	6200
6	19	87	15	4	64	2434	10	52	0	39	20	27	2928	5699
7	1695	5809	1173	406	9	435	93	0	0	0	552	5	9	10186
8	412	95	5	0	0	0	33	0	1	0	0	202	0	748
9	983	664	158	125	79	1491	160	3	41	189	733	432	708	5766
tot	6954	14473	2553	716	199	5364	357	193	233	778	1506	42102	81181	156609

INTERPRETED CLASSES

1 = water
2 = agricultural land
3 = pine forest
4 = spruce forest
5 = mixed forest
6 = decidious forest
7 = sapling stand
8 = marsh
9 = unclassified

REFERENCE CLASSES

1 = pine forest
2 = spruce forest
3 = mixed forest
4 = decidious forest
5 = clearing
6 = sapling stand
7 = open marsh
8 = meadow
9 = quarry
10 = built-up area
11 = forested marsh (pine)
12 = water
13 = agricultural land

APPENDIX 9.2

CONFUSION MATRIX OF INTERPRETATION OF IFAG (XS-data)

In this matrix all reference pixels (feature boundary pixels exepted) were tested. The proportional areas of the classes do not match with the actual areas covered by the same classes in the field. Thus accuracy estimates can not be calculated using this matrix

REFERENCE CLASSES (without feature boundaries)

CLAS.	1	2	3	4	5	6	7	8	9	10	11	12	13	total
1	0	0	0	0	0	0	0	0	0	0	0	40469	0	40469
2	6240	13656	2313	319	45	761	245	0	2	23	961	330	9	24904
3	0	1	0	0	0	0	22	0	0	0	0	490	0	513
4	72	239	104	163	30	2012	30	52	3	39	21	5	2401	5171
5	0	0	0	2	0	21	0	18	0	0	0	0	4426	4467
6	2	48	0	28	5	585	5	55	0	79	0	1	14016	14824
7	0	0	0	0	2	0	0	1	0	1	0	0	2706	2710
8	19	49	5	1	29	973	8	3	0	66	8	22	1760	2943
9	0	11	1	0	2	69	2	11	0	109	0	9	12123	12337
10	0	7	4	0	1	2	0	1	2	26	0	0	1287	1330
11	0	13	0	0	0	2	0	11	49	88	0	1	23771	23935
12	2	5	0	0	0	0	0	0	8	2	0	8	45	70
13	38	30	3	1	22	77	0	0	1	22	0	0	272	466
14	5	13	0	0	2	2	0	17	102	125	0	1	9464	9731
15	9	92	80	193	0	43	0	0	0	1	58	0	1	477
16	567	309	43	9	61	817	45	24	66	197	458	766	8900	12262
tot	6954	14473	2553	716	199	5364	357	193	233	778	1506	42102	81181	156609

INTERPRETED CLASSES

1 = water
2 = forest 1
3 = forest 2
4 = forest 3
5 = agricultural area 1
6 = agricultural area 2
7 = agricultural area 3
8 = agricultural area 4
9 = agricultural area 5
10 = agricultural area 6
11 = agricultural area 7
12 = agricultural area 8
13 = agricultural area 9
14 = agricultural area 10
15 = agricultural area 11
16 = unclassified

REFERENCE CLASSES

1 = pine forest
2 = spruce forest
3 = mixed forest
4 = decidious forest
5 = clering
6 = sapling stand
7 = open marsh
8 = meadow
9 = quarry
10 = built-up area
11 = forested marsh (pine)
12 = water
13 = field

APPENDIX 9.3

CONFUSION MATRIX OF INTERPRETATION OF LMV1 (XS-data)

In this matrix all reference pixels (feature boundary pixels exepted) were tested. The proportional areas of the classes do not match with the actual areas covered by the same classes in the field. Thus accuracy estimates can not be calculated using this matrix

REFERENCE CLASSES (without feature boundaries)

CLAS.	1	2	3	4	5	6	7	8	9	10	11	12	13	total
1	3490	1393	251	47	69	1355	251	0	5	0	1113	117	238	8329
2	3070	11435	1687	44	5	93	24	0	0	0	149	76	42	16625
3	167	1221	516	582	2	358	39	0	3	0	228	0	288	3404
4	68	30	2	0	37	130	0	0	2	1	9	1	186	466
5	76	201	59	21	61	3306	27	27	0	2	2	11	3251	7044
6	4	18	0	0	0	0	0	0	197	7	0	0	281	507
7	22	0	0	0	0	0	12	0	0	0	0	41849	6	41889
8	0	2	0	0	0	1	0	0	0	0	0	0	81	84
9	4	16	10	0	0	0	0	28	8	681	0	33	1801	2581
10	0	0	3	0	0	0	0	0	0	0	0	0	25	28
11	0	0	0	0	0	0	0	0	0	38	0	0	27	65
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	30	68	4	0	5	20	0	0	2	2	0	0	470	601
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	23	89	21	22	20	101	4	138	16	47	5	15	74485	74986
tot	6954	14473	2553	716	199	5364	357	193	233	778	1506	42102	81181	156609

INTERPRETED CLASSES

1 = marshes
2 = coniferous forest
3 = deciduous forest
4 = felled forest
5 = sapling stand
6 = gravel
7 = water
8 = power lines
9 = built-up areas
10 = main roads
11 = streets
12 = railways
13 = smaller roads
14 = airport
15 = fields/meadows

REFERENCE CLASSES

1 = pine forest
2 = spruce forest
3 = mixed forest
4 = decidious forest
5 = clering
6 = sapling stand
7 = open marsh
8 = meadow
9 = quarry
10 = built-up area
11 = forested marsh (pine)
12 = water
13 = agricultural land

ERROR MATRICES OF ROADS (lengths in meters)

IGN1 (XS)

	CLASS ON MAP						TOTAL
	IA	IB	IIAB	IIIAB	CARTROAD	OTHER	
CLASSIFIED I A	4457	1842	0	0	0	0	6299
I B	0	41456	9745	0	0	0	51201
II AB	0	0	77673	9341	0	1265	88279
III AB	0	0	31889	82941	18313	21345	154488
Cartroad	0	0	0	0	3061	9515	12576
Omission(Tot)	2	1644	29672	148393	402274	-	581985
TOTAL	4459	44942	148979	240675	423648	32125	894828

LMV 1 (XS)

	CLASS ON MAP						TOTAL
	IA	IB	IIAB	IIIAB	CARTROAD	OTHER	
CLASSIFIED Main Road	4528	44031	9758	0	0	0	58317
Smaller Road	0	0	109073	116655	21173	30803	277704
Street	0	0	5867	581	0	0	6448
Omission(Tot)	(-69)	911	24281	123439	402475	-	551037
TOTAL	4459	44942	148979	240675	423648	30803	893506

GL 2 (2xP)

	CLASS ON MAP				TOTAL
	IIAB	IIIAB	CARTROAD	OTHER	
CLASSIFIED II AB	32903	4339	236	1452	38930
III AB/Cartroad	1071	29668	60448	1164	92351
Omission(Tot)	(-179)	3614	50868	-	54303
TOTAL	33795	37621	111552	2616	185584

APPENDIX 10 (continued)

GL 3 (XS/P)

	CLASS ON MAP				TOTAL
	IIAB	IIIAB	CARTROAD	OTHER	
CLASSIFIED Main Road	26515	14067	0	0	40582
Secondary Road	7312	16694	12199	617	36822
Omission(Tot)	148	6860	99353	-	106361
TOTAL	33975	37621	111552	617	183765

IGN 2 (2xP)

	CLASS ON MAP					TOTAL
	IB	IIAB	IIIAB	CARTROAD	OTHER	
CLASSIFIED I B	0	10457	0	0	0	10457
II AB	0	14625	955	0	0	15580
III AB	0	8906	29228	13345	0	51479
Cartroad	0	0	3470	21892	11193	36555
Omission(Tot)	0	(-193)	3968	76315	-	80090
TOTAL	0	33795	37621	111552	11193	194161

LMV 2 (XS/P)

	CLASS ON MAP				TOTAL
	IIAB	IIIAB	CARTROAD	OTHER	
CLASSIFIED Main Road	15936	0	0	0	15936
Secondary Road	17793	34227	39112	15943	107075
Omission(Tot)	66	3394	72440	-	75900
TOTAL(MAP)	33795	37621	111552	15943	198911

SKV (P)

	CLASS ON MAP			TOTAL
	IIAB	IIIAB	OTHER	
CLASSIFIED Secondary road	33286	30809	854	64949
Omission	509	6812	-	7321
TOTAL	33795	37621	854	71416

LIST OF THE OEEPE PUBLICATIONS

State — October 1990

A. Official publications

1 *Trombetti, C.:* „Activité de la Commission A de l'OEEPE de 1960 à 1964" — *Cunietti, M.:* „Activité de la Commission B de l'OEEPE pendant la période septembre 1960—janvier 1964" — *Förstner, R.:* „Rapport sur les travaux et les résultats de la Commission C de l'OEEPE (1960—1964)" — *Neumaier, K.:* „Rapport de la Commission E pour Lisbonne" — *Weele, A.J. v. d.:* „Report of Commission F." — Frankfurt a. M. 1964, 50 pages with 7 tables and 9 annexes.

2 *Neumaier, K.:* „Essais d'interprétation de »Bedford« et de »Waterbury«. Rapport commun établi par les Centres de la Commission E de l'OEEPE ayant participé aux tests" — „The Interpretation Tests of »Bedford« and »Waterbury«. Common Report Established by all Participating Centres of Commission E of OEEPE" — „Essais de restitution »Bloc Suisse«. Rapport commun établi par les Centres de la Commission E de l'OEEPE ayant participé aux tests" — „Test »Schweizer Block«. Joint Report of all Centres of Commission E of OEEPE." — Frankfurt a. M. 1966, 60 pages with 44 annexes.

3 *Cunietti, M.:* „Emploi des blocs de bandes pour la cartographie à grande échelle — Résultats des recherches expérimentales organisées par la Commission B de l'O.E.E.P.E. au cours de la période 1959—1966" — „Use of Strips Connected to Blocks for Large Scale Mapping — Results of Experimental Research Organized by Commission B of the O.E.E.P.E. from 1959 through 1966." — Frankfurt a. M. 1968, 157 pages with 50 figures and 24 tables.

4 *Förstner, R.:* „Sur la précision de mesures photogrammétriques de coordonnées en terrain montagneux. Rapport sur les résultats de l'essai de Reichenbach de la Commission C de l'OEEPE" — „The Accuracy of Photogrammetric Co-ordinate Measurements in Mountainous Terrain. Report on the Results of the Reichenbach Test Commission C of the OEEPE." — Frankfurt a. M. 1968, Part I: 145 pages with 9 figures; Part II: 23 pages with 65 tables.

5 *Trombetti, C.:* „Les recherches expérimentales exécutées sur de longues bandes par la Commission A de l'OEEPE." — Frankfurt a. M. 1972, 41 pages with 1 figure, 2 tables, 96 annexes and 19 plates.

6 *Neumaier, K.:* „Essai d'interprétation. Rapports des Centres de la Commission E de l'OEEPE." — Frankfurt a. M. 1972, 38 pages with 12 tables and 5 annexes.

7 *Wiser, P.:* „Etude expérimentale de l'aérotriangulation semi-analytique. Rapport sur l'essai »Gramastetten«." — Frankfurt a. M. 1972, 36 pages with 6 figures and 8 tables.

8 „Proceedings of the OEEPE Symposium on Experimental Research on Accuracy of Aerial Triangulation (Results of Oberschwaben Tests)"
Ackermann, F.: „On Statistical Investigation into the Accuracy of Aerial Triangulation. The Test Project Oberschwaben" — „Recherches statistiques sur la précision de l'aérotriangulation. Le champ d'essai Oberschwaben" — *Belzner, H.:* „The Planning. Establishing and Flying of the Test Field Oberschwaben" — *Stark, E.:* Testblock Oberschwaben, Programme I. Results of Strip Adjustments" — *Ackermann, F.:* „Testblock Oberschwaben, Program I. Results of Block-Adjustment by Independent Models" — *Ebner, H.:* Comparison of Different Methods of Block Adjustment" — *Wiser, P.:* „Propositions pour le traitement des erreurs non-accidentelles" — *Camps, F.:* „Résultats obtenus dans le cadre du project Oberschwaben 2A" — *Cunietti, M.; Vanossi, A.:* „Etude statistique expérimentale des erreurs d'enchaînement des photogrammes" — *Kupfer, G.:* „Image Geometry as Obtained from Rheidt Test Area Photography" — *Förstner, R.:* „The Signal-Field of Baustetten. A Short Report" — *Visser, J.; Leberl, F.; Kure, J.:* „OEEPE Oberschwaben Reseau Investigations" — *Bauer, H.:* „Compensation of Systematic Errors by Analytical Block Adjustment with Common Image Deformation Parameters." — Frankfurt a. M. 1973, 350 pages with 119 figures, 68 tables and 1 annex.

9 *Beck, W.:* „The Production of Topographic Maps at 1 : 10,000 by Photogrammetric Methods. — With statistical evaluations, reproductions, style sheet and sample fragments by Landesvermessungsamt Baden-Württemberg, Stuttgart." — Frankfurt a. M. 1976, 89 pages with 10 figures, 20 tables and 20 annexes.

10 „Résultats complémentaires de l'essai d'«Oberriet» de la Commission C de l'OEEPE — Further Results of the Photogrammetric Tests of «Oberriet» of the Commission C of the OEEPE"
Härry, H.: „Mesure de points de terrain non signalisés dans le champ d'essai d'«Oberriet» — Measurements of Non-Signalized Points in the Test Field «Oberriet» (Abstract)" — *Stickler, A.; Waldhäusl, P.:* „Restitution graphique des points et des lignes non signalisés et leur comparaison avec des résultats de mesures sur le terrain dans le champ d'essai d'«Oberriet» — Graphical Plotting of Non-Signalized Points and Lines, and Comparison with Terrestrial Surveys in the Test Field «Oberriet»" — *Förstner, R.:* „Résultats complémentaires des transformations de coordonnées de l'essai d'«Oberriet» de la Commission C de l'OEEPE — Further Results from Co-ordinate Transformations of the Test «Oberriet» of Commission C of the OEEPE" — *Schürer, K.:* „Comparaison des distances d'«Oberriet» — Comparison of Distances of «Oberriet» (Abstract)." — Frankfurt a. M. 1975, 158 pages with 22 figures and 26 tables.

11 „25 années de l'OEEPE"
Verlaine, R.: „25 années d'activité de l'OEEPE" — „25 Years of OEEPE (Summary)" — *Baarda, W.:* „Mathematical Models." — Frankfurt a. M. 1979, 104 pages with 22 figures.

12 *Spiess, E.:* „Revision of 1 : 25,000 Topographic Maps by Photogrammetric Methods." — Frankfurt a. M. 1985, 228 pages with 102 figures and 30 tables.

13 *Timmerman, J.; Roos, P. A.; Schürer, K.; Förstner, R.:* On the Accuracy of Photogrammetric Measurements of Buildings — Report on the Results of the Test "Dordrecht", Carried out by Commission C of the OEEPE. — Frankfurt a. M. 1982, 144 pages with 14 figures and 36 tables.

14 *Thompson, C. N.:* Test of Digitising Methods. — Frankfurt a. M. 1984, 120 pages with 38 figures and 18 tables.

15 *Jaakkola, M.; Brindöpke, W.; Kölbl, O.; Noukka, P.:* Optimal Emulsions for Large-Scale Mapping — Test of "Steinwedel" — Commission C of the OEEPE 1981—84. — Frankfurt a. M. 1985, 102 pages with 53 figures.

16 *Waldhäusl, P.:* Results of the Vienna Test of OEEPE Commission C. — *Kölbl, O.:* Photogrammetric Versus Terrestrial Town Survey. — Frankfurt a. M. 1986, 57 pages with 16 figures, 10 tables and 7 annexes.

17 *Commission E of the OEEPE:* Influences of Reproduction Techniques on the Identification of Topographic Details on Orthophotomaps. — Frankfurt a. M. 1986, 138 pages with 51 figures, 25 tables and 6 appendices.

18 *Förstner, W.:* Final Report on the Joint Test on Gross Error Detection of OEEPE and ISP WG III/1. — Frankfurt a. M. 1986, 97 pages with 27 tables and 20 figures.

19 *Dowman, I. J.; Ducher, G.:* Spacelab Metric Camera Experiment — Test of Image Accuracy. — Frankfurt a. M. 1987, 112 pages with 13 figures, 25 tables and 7 appendices.

20 *Eichhorn, G.:* Summary of Replies to Questionnaire on Land Information Systems — Commission V — Land Information Systems. — Frankfurt a. M. 1988, 129 pages with 49 tables and 1 annex.

21 *Kölbl, O.:* Proceedings of the Workshop on Cadastral Renovation — Ecole polytechnique fédérale, Lausanne, 9—11 September, 1987. — Frankfurt a. M. 1988, 337 pages with figures, tables and appendices.

22 *Rollin, J.; Dowman, I. J.:* Map Compilation and Revision in Developing Areas — Test of Large Format Camera Imagery. — Frankfurt a. M. 1988, 35 pages with 3 figures, 9 tables and 3 appendices.

23 *Drummond, J.* (ed.): Automatic Digitizing — A Report Submitted by a Working Group of Commission D (Photogrammetry and Cartography). — Frankfurt a. M. 1990, 224 pages with 85 figures, 6 tables and 6 appendices.

B. Special publications

— Special Publications O.E.E.P.E. — Number I

Solaini, L.; Trombetti, C.: Relation sur les travaux préliminaires de la Commission A (Triangulation aérienne aux petites et aux moyennes échelles) de l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (O.E.E.P.E.). I^{ère} Partie: Programme et organisation du travail. — *Solaini, L.; Belfiore, P.:* Travaux préliminaires de la Commission B de l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (O.E.E.P.E.) (Triangulations aériennes aux grandes échelles). — *Solaini, L.; Trombetti, C.; Belfiore, P.:* Rapport sur les travaux expérimentaux de triangulation aérienne exécutés par l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (Commission A et B). — *Lehmann, G.:* Compte rendu des travaux de la Commission C de l'O.E.E.P.E. effectués jusqu'à présent. — *Gotthardt, E.:* O.E.E.P.E. Commission C. Compte-rendu de la restitution à la Technischen Hochschule, Stuttgart, des vols d'essai du groupe I du terrain d'Oberriet. — *Brucklacher, W.:* Compte-rendu du centre «Zeiss-Aerotopograph» sur les restitutions pour la Commission C de l'O.E.E.P.E. (Restitution de la bande de vol, groupe I, vol. No. 5). — *Förstner, R.:* O.E.E.P.E. Commission C. Rapport sur la restitution effectuée dans l'Institut für Angewandte Geodäsie, Francfort sur le Main. Terrain d'essai d'Oberriet les vols No. 1 et 3 (groupe I). — I.T.C., Delft: Commission C, O.E.E.P.E. Déroulement chronologique des observations. — Photogrammetria XII (1955—1956) 3, Amsterdam 1956, pp. 79—199 with 12 figures and 11 tables.

— Publications spéciales de l'O.E.E.P.E. — Numéro II

Solaini, L.; Trombetti, C.: Relations sur les travaux préliminaires de la Commission A (Triangulation aérienne aux petites et aux moyennes échelles) de l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (O.E.E.P.E.). 2^{e} partie. Prises de vues et points de contrôle. — *Gotthardt, E.:* Rapport sur les premiers résultats de l'essai d'«Oberriet» de la Commission C de l'O.E.E.P.E. — Photogrammetria XV (1958—1959) 3, Amsterdam 1959, pp. 77—148 with 15 figures and 12 tables.

— *Trombetti, C.:* Travaux de prises de vues et préparation sur le terrain effectuées dans le 1958 sur le nouveau polygone italien pour la Commission A de l'OEEPE. — Florence 1959, 16 pages with 109 tables.

— *Trombetti, C.; Fondelli, M.:* Aérotriangulation analogique solaire. — Firence 1961, 111 pages, with 14 figures and 43 tables.

— Publications spéciales de l'O.E.E.P.E. — Numéro III

Solaini, L.; Trombetti, C.: Rapport sur les résultats des travaux d'enchaînement et de compensation exécutés pour la Commission A de l'O. E. E. P. E. jusqu'au mois de Janvier 1960. Tome 1: Tableaux et texte. Tome 2: Atlas. — Photogrammetria XVII (1960—1961) 4, Amsterdam 1961, pp. 119—326 with 69 figures and 18 tables.

— „OEEPE — Sonderveröffentlichung Nr. 1"

Gigas, E.: „Beitrag zur Geschichte der Europäischen Organisation für photogrammetrische experimentelle Untersuchungen" — *N. N.:* „Vereinbarung über die Gründung einer Europäischen Organisation für photogrammetrische experimentelle Untersuchungen" — „Zusatzprotokoll" — *Gigas, E.:* „Der Sechserausschuß" — *Brucklacher, W.:* „Kurzbericht über die Arbeiten in der Kommission A der OEEPE" — *Cunietti, M.:* „Kurzbericht des Präsidenten der Kommission B über die gegenwärtigen Versuche und Untersuchungen" — *Förstner, R.:* „Kurzbericht über die Arbeiten in der Kommission B der OEEPE" — „Kurzbericht über die Arbeiten in der Kommission C der OEEPE" — *Belzner, H.:* „Kurzbericht über die Arbeiten in der Kommission E der OEEPE" — *Schwidefsky, K.:* „Kurzbericht über die Arbeiten in der Kommission F der OEEPE" — *Meier, H.-K.:* „Kurzbericht über die Tätigkeit der Untergruppe „Numerische Verfahren" in der Kommission F der OEEPE" — *Belzner, H.:* „Versuchsfelder für internationale Versuchs- und Forschungsarbeiten." — Nachr. Kt.- u. Vermesss.-wes., R. V, Nr. 2, Frankfurt a. M. 1962, 41 pages with 3 tables and 7 annexes.

— *Rinner, K.:* Analytisch-photogrammetrische Triangulation eines Teststreifens der OEEPE. — Österr. Z. Vermess.-wes., OEEPE-Sonderveröff. Nr. 1, Wien 1962, 31 pages.

— *Neumaier, K.; Kasper, H.:* Untersuchungen zur Aerotriangulation von Überweitwinkelaufnahmen. — Österr. Z. Vermess.-wes., OEEPE-Sonderveröff. Nr. 2, Wien 1965, 4 pages with 4 annexes.

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— „OEEPE — Sonderveröffentlichung Nr. 3"

Neumaier, K.: „Versuch »Bedford« und »Waterbury«. Gemeinsamer Bericht aller Zentren der Kommission E der OEEPE" — „Versuch »Schweizer Block«. Gemeinsamer Bericht aller Zentren der Kommission E der OEEPE." — Nachr. Kt.- u. Vermess.-wes., R. V, Nr. 13, Frankfurt a. M. 1966, 30 pages with 44 annexes.

— *Stickler, A.; Waldhäusl, P.:* Interpretation der vorläufigen Ergebnisse der Versuche der Kommission C der OEEPE aus der Sicht des Zentrums Wien. — Österr. Z. Vermess.-wes., OEEPE-Sonderveröff. (Publ. Spéc.) Nr. 3, Wien 1967, 4 pages with 2 figures and 9 tables.

— „OEEPE — Sonderveröffentlichung Nr. 4"

Schürer, K.: „Die Höhenmeßgenauigkeit einfacher photogrammetrischer Kartiergeräte. Bemerkungen zum Versuch »Schweizer Block« der Kommission E der OEEPE." — Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M., 1968, 25 pages with 7 figures and 3 tables.

- „OEEPE – Sonderveröffentlichung Nr. 5"

  Förstner, R.: „Über die Genauigkeit der photogrammetrischen Koordinatenmessung in bergigem Gelände. Bericht über die Ergebnisse des Versuchs Reichenbach der Kommission C der OEEPE." – Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1969, Part I: 74 pages with 9 figures; Part II: 65 tables.

- „OEEPE – Sonderveröffentlichung Nr. 6"

  Knorr, H.: „Die Europäische Organisation für experimentelle photogrammetrische Untersuchungen – OEEPE – in den Jahren 1962 bis 1970." – Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1971, 44 pages with 1 figure and 3 tables.

- „OEEPE – Sonderveröffentlichung Nr. D-7"

  Förstner, R.: „Das Versuchsfeld Reichenbach der OEEPE." – Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1972, 191 pages with 49 figures and 38 tables.

- „OEEPE – Sonderveröffentlichung Nr. D-8"

  Neumaier, K.: „Interpretationsversuch. Berichte der Zentren der Kommission E der OEEPE." – Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1972, 33 pages with 12 tables and 5 annexes.

- „OEEPE – Sonderveröffentlichung Nr. D-9"

  Beck, W.: „Herstellung topographischer Karten 1 : 10 000 auf photogrammetrischem Weg. Mit statistischen Auswertungen, Reproduktionen, Musterblatt und Kartenmustern des Landesvermessungsamts Baden-Württemberg, Stuttgart." – Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1976, 65 pages with 10 figures, 20 tables and 20 annexes.

- „OEEPE – Sonderveröffentlichung Nr. D-10"

  Weitere Ergebnisse des Meßversuchs „Oberriet" der Kommission C der OEEPE. *Härry, H.:* „Messungen an nicht signalisierten Geländepunkten im Versuchsfeld «Oberriet»" – *Stickler, A.; Waldhäusl, P.:* „Graphische Auswertung nicht signalisierter Punkte und Linien und deren Vergleich mit Feldmessungsergebnissen im Versuchsfeld «Oberriet»" – *Förstner, R.:* „Weitere Ergebnisse aus Koordinatentransformationen des Versuchs «Oberriet» der Kommission C der OEEPE" – *Schürer, K.:* „Streckenvergleich «Oberriet»." – Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1975, 116 pages with 22 figures and 26 tables.

- „OEEPE – Sonderveröffentlichung Nr. D-11"

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