

EVALUATION OF SPOT DATA FOR TOPOGRAPHIC MAP REVISION AT THE NATIONAL LAND SURVEY OF SWEDEN

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ABSTRACT:

In a project carried out jointly by the National Land Survey (NLS) and the Swedish Space Corporation (SSC), SPOT data has been tested for map revision purposes. The main application focused on is a frequent revision of the new topographic map series at the scale of 1:50 000. The map features of current interest are roads, clearings and built-up areas. Comparison has been made with aerial photos. Results show no or minor differences in interpretations of roads and clearings from aerial photos, SPOT PAN or SPOT XS regarding the different accuracy measures: completeness, shape and geometric accuracy. For urban areas, it is possible to interpret the delimitations of new areas for revision. The result also indicate that training is needed to fully take advantage of the multispectral images of SPOT. Costs and accessibility for SPOT data vs aerial photos are evaluated. Current work involves digital revision methods with SPOT data at NLS.

KEY WORDS: Topographic Map Revision, SPOT Data, Satellite Remote Sensing Application, Image Interpretation, Digital Revision Methods.

1. BACKGROUND

1.1 The new topographic map of Sweden

In 1990, the first map sheets of the new topographic map series in Sweden at the scale of 1:50 000 was published. The maps are produced by the National Land Survey of Sweden (NLS, in Swedish: *Lantmäteriverket*) in Gävle. The new map series is produced completely by digital methods. All objects are stored in digital databases. The maps also contain an increased amount of feature types compared to earlier maps, e.g. clearings, bedrock outcrops and cultivated areas. The new map is based on aerial photos and field control.

Introducing clearings in the map requires a rather frequent revision interval. The planned revision cycle of the new map series is: a frequent revision every 5 years involving a few map feature types; an extended revision every 10 years concerning a larger set of feature types; and finally production of a new map including field work after 20 years.

Revision here implies image interpretation without field control. What type of image material, i.e. satellite imagery or aerial photos from different altitudes, to be used for these future revisions has not yet been decided.

1.2 The SPOT satellite

The French SPOT earth resources satellite carries high resolution sensors producing data and images of the earth. The panchromatic (PAN) mode has a pixelsize of 10 meters and the multispectral (XS) mode, in the visible and near-infrared part of the electromagnetic spectrum, has a pixelsize of 20 meters. Sweden cooperates with France in the SPOT project, and the two main receiving stations are situated in Toulouse, France and in Kiruna, in the far north of Sweden.

SPOT is a near-polar orbiting satellite covering the earth in 26 days. SPOT carries two sensors which can, besides nadir viewing, be programmed to point off-nadir to the side of the current satellite track. With nadir viewing a certain satellite "scene" is revisited every 26 days. The further away from the equator, the closer the distance is between the satellite tracks, causing overlapping scenes. In central Sweden, for instance, a particular area on the ground is covered approximately every 13 days with nadir viewing. Using the pointing capability, however, the revisit cycle dramatically increases to a matter of day or days, all depending on the latitude and the pointing angle of the sensor.

2. AIM OF THE STUDY

The main objective for this study, carried out in cooperation between the National Land Survey and the Swedish Space Corporation, was to find out if SPOT images could be used in the interpretation process for the future frequent revision of roads, clearings and built-up areas in the new topographic map at the scale of 1:50 000.

The alternative method for this revision type would be using aerial photos from high altitude (9 200 meters, negative scale 1:60 000) or very high altitude (13 200 meters, negative scale 1:150 000).

Costs and accessibility were also to be investigated.

3. THE STUDY

3.1 Method

SPOT images, on one hand, and aerial photos, on the other, were interpreted for map revision purposes. The results were compared using field controlled data.

3.2 Test area

The topographic sheet Östhammar 12I SV at scale 1:50 000 located in the central part of Sweden was chosen for the tests. The study was carried out during the production of the new map in this area, for which reason field data was available. The northwest and southwest quadrants of the map, each covering 12 500 meters x 12 500 meters, were used in the study.

The area consists mainly of homogeneous forested areas with a rather large number of clearings, and also of cultivated areas, marsh land and a few minor urban areas.

3.3 SPOT images

SPOT data, both PAN and XS, over the test area was registered in May, 1990. The near-nadir images were precision corrected using map control points to fit the Swedish national grid and sampled to a pixelsize of 5 meters. For each map quadrant high quality diapositives at scale 1:67 000 were produced by a filmrecorder. From these, film enlargements at scale 1:25 000 were finally made. It is essential for the quality of the final images that the photographic enlargement factor is, such as in this case, held low.

The SPOT images were produced at SSC Satellitbild in Kiruna using standard production methods. Digital data was also available.

In the study, the interpretation of the films at scale 1:25 000 was carried out using a light table.

3.4 New aerial photos

The high altitude b/w aerial photos (9 200 meters, negative scale 1:60 000) used in the study, as a comparison to the satellite imagery, were taken in May, 1989. Up-to-date very high altitude photos (13 200 m) were not available over the area.

In the study, orthophotos enlarged to scale 1:25 000 were used for the interpretation along with stereointerpretation at scale 1:60 000.

3.5 Field controlled new map

The new topographic map over the test area was used for the evaluation of interpretation results from the SPOT images and the aerial photos used in the study. The new map is in other words regarded as the true representation of the area.

The new map is based on interpretation of aerial photos from May, 1989, altitude 9 200 meters, and field control during the summer of 1990. Photointerpretation for the new map was done using orthophotos at scale 1:25 000.

Stereointerpretation was also carried out, at scale 1:60 000 or at the enlarged scale 1:25 000.

In the new map, there are two classes of forested area: forest and clearings. Clearings are those stands with a tree height of less than 1.5 meters.

3.6 Interpretation of SPOT and aerial images in study

Initially, the interpreters involved in the interpretations were introduced to satellite remote sensing and interpretation. A third quadrant of the map was used in this step. The three interpreters from the Land Survey engaged in this study, all have a very long experience of aerial photo interpretation, but less experience with satellite imagery, especially multispectral ones.

The new map, although digitally stored, is based on visual image interpretation. Conventional visual interpretation methods has therefore been used also for this study, thereby focusing on differences in the quality of the image materials rather than the interpretation methods used. However, interactive digital interpretation of image data on a display of an image processing system was also carried out.

SPOT and aerial photos were interpreted by the three NLS interpreters for the two map quadrants covering the test area, see table 1.

Table 1. SPOT and aerial images covering two map quadrants were interpreted according to the model shown below. Two interpreters were involved to ensure independent interpretations in different image materials covering the same area, see # 2, 3, 4 & 5. A third interpreter was engaged in order to quantify any differences between the interpreters, see # 1 and 2. Interpretation # 6 and 7 (SPOT XS) was made a month after the others, thus minimizing the influence from # 3 and 5 (SPOT PAN) respectively.

Interpretation #	Interpreter	Image material	Map quadrant
<i>Visual interpretation.</i>			
1	C	aerial photo	nw
2	A	aerial photo	nw
3	B	SPOT PAN	nw
4	B	aerial photo	sw
5	A	SPOT PAN	sw
6	B	SPOT XS	nw
7	A	SPOT XS	sw
<i>Interactive digital interpretation.</i>			
8	NLS, SSC	SPOT XS	part of sw

As for any map revision operation, old maps and aerial photos were available during the interpretations in this study.

Since the old map series does not contain clearings, the old aerial photos (1981, altitude 3000 m) was essential for the up-dating of clearings in this study.

In the test area, which was chosen for its extended forested areas, there was little or no built-up area to revise. Built-up areas were therefore not interpreted. The evaluation made in this study was based on general experience from SPOT images.

4. RESULTS

4.1 General

Air photos have a higher geometric resolution than satellite images and are for that reason preferred by the interpreters. The NLS does not have so much experience of multispectral satellite images and these are in some cases considered too blurry at the interpretation scale 1:25 000. To fully benefit from these images the interpretation methodology needs to be further developed. The geometric position accuracy, however, is very high in the SPOT images.

4.2 Adjustments to the interpretations

Since the new aerial photos in the study and the satellite images differed one year, all changes between 1989 and 1990 were disregarded.

4.3 Accuracy types and measures

Three different accuracy types were defined:

- the *completeness*, i.e. how many roads, clearings etc. were detected?
- the *shape consistency* of the features. An erroneous shape of a clearing is for instance caused by including an area of sapling stands in the clearing.
- the *geometric accuracy* in the delimitations. This depends on the geometric resolution of the sensor and preprocessing of the image, and of the sharpness or contrast of the particular entity. A road is for instance expected to have a higher geometric accuracy than a clear-cut, depending on narrow zones of deciduous vegetation often delimiting the clearings.

It is difficult to distinctly separate the accuracy types from each other. A clearing only partly interpreted will be considered to have an erroneous shape. Alternatively it could be regarded as two entities of which one is correct and the other wrong (completeness). Also the geometric accuracy and the shape could be discussed. Including a larger fuzzy area of vegetation surrounding a clearing in the interpretation is here considered as influencing the shape and not the geometric accuracy.

The following accuracy measures has been used for the above accuracy types.

Completeness:

$$\frac{2 \times \# \text{correctly interpreted clearings}}{\# \text{clearings in new map} + \# \text{clearings interpreted}}$$

The formula, which was used for clearings, takes into consideration both the number of clearings in the true map and the total number of clearings in the interpretations. Thereby, both errors of omission and commission are taken into account.

For roads, a revision almost exclusively means new roads, and only errors of omission is likely to occur. The number of interpreted new roads compared to number of new roads in the true map were therefore used.

Shape consistency: A subjective visual measure was used. For clearings for instance, only those who significantly differ in size compared to the true map was regarded, i.e. double or half the size.

Geometric accuracy: A visual comparison was made to the true map.

4.4 Roads - completeness and shape consistency

The number of new roads in the test area is only about 20. No significant difference between the interpretations in the different image materials are found. However, roads on the actual clearings is found to cause some problems in SPOT XS. This is probably not the case while working with digital images, since these can be contrast stretched interactively in the different parts to enhance different features. The photographic images in this study, were stretched in regard to the forested areas.

4.5 Roads - geometric accuracy

Using the pen chosen by the interpreters for the drafting (approximate width one pixel), no difference of significance to this application is found between the interpretations.

4.6 Clearings - completeness and shape consistency

The results of the interpretations are shown in table 2a and 2b. The total number of clearings in the area is over 200.

The results seem to indicate, somewhat surprisingly, that the approximate accuracy in revision/interpretation of clearings is 65-70%, independent of image material.

The relative accuracy between interpretation # 1 and 2 (two interpreters, same area and material) is a little higher, around 80%, indicating a high agreement between different interpreters.

Interpretation # 4 is an outlier, where the interpreter obviously has been very careful in the classification. Out of 50 interpreted clearings, 49 are correct.

The interpretations of clearings in the study were naturally only made within forested areas of the map. In the topographic map, clearings are defined as forested areas with tree heights less than 1.5 meters. The misinterpretations are therefore mainly areas within the zone between clearings and forest, i.e. around 1.5 m. It is a known fact that, even in aerial photos (9 200 m), it is not possible to reliably interpret the 1.5 meter limit.

Table 2a. *Clearings, completeness. See table 1 for details of the interpretations.*

Interpretation	Number of clearings in field-checked new map	Total number of clearings interpreted in study	Number correctly interpreted	Accuracy
<i>Northwest quadrant</i>		79		
1. Air photos 9 200 m (C)	-	67	53	73%
2. Air photos 9 200 m (A)	-	49	43	67%
3. SPOT PAN (B)	-	70	51	68%
6. SPOT XS (B)	-	53	43	65%
<i>Southwest quadrant</i>		135		
4. Air photos 9 200 m (B)	-	50	49	53%
5. SPOT PAN (A)	-	86	74	67%
7. SPOT XS (A)	-	75	68	65%
8. SPOT XS digital data	-	-	-	65-77% ¹⁾

¹⁾ Not fully comparable to the others. Interpreted in two classes according to the confidence in the classification. For comparison with the others, the accuracy lies somewhere between 65 and 77 %.

Table 2b. *Clearings, shape consistency.*

Inter-pretation	Total # clearings interpreted in study	# interpreted clearings with erroneous shape
<i>Northwest</i>		
1	67	5
2	49	2
3	70	7
6	53	5
<i>Southwest</i>		
4	50	8
5	86	19
7	75	16

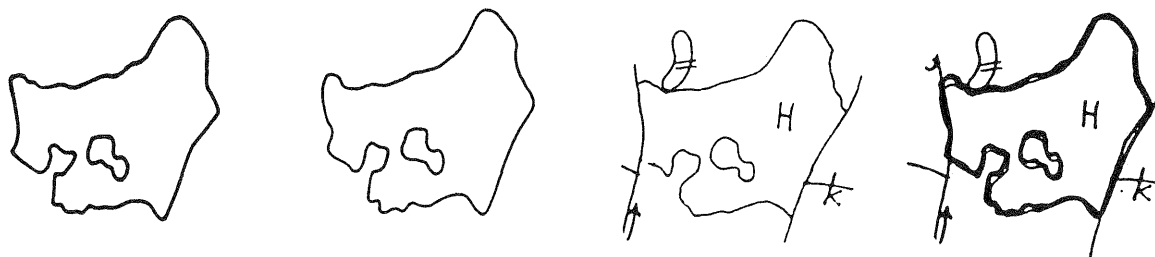


Figure 1: *Clearings, geometric accuracy. Comparing the delimitations from different materials. From left - first: SPOT PAN; second: SPOT XS; third: the manuscript for the new topographic map; fourth: all three superimposed. Scale 1:25 000.*

The interpretations were actually to a great extent based on comparing the old aerial photos (since the old map does not contain clearings) to the new ones and on the knowledge of the average growth in the area. It was estimated that the length of time from cutting to 1.5 m was the same as between the old and new images.

For a good result in future revision interpretations, it is of great importance to know the approximate age of the clearings, since the age is somewhat correlated to the tree height.

A further analysis of misinterpretations shows that some very small clearings were left out in some of the interpretations (although they were large enough to be represented in the map). Another fact was that a number of stands that were clearings in the old map, still were clearings in 1989/90, because the renewal in the test area was not as quick as it was assumed to be.

4.7 Clearings - geometric accuracy

Figure 1 shows one clearing interpreted in different image materials. No significant difference in the geometric accuracy of the delimitations, of importance to this application, is found between the materials.

4.8 Built-up areas

Experience shows that delimitations of new built-up areas in SPOT images can be interpreted while the classification into different categories of urban areas is not possible. For aerial photos the situation is much the same.

4.9 Time

The amount of time spent on the different interpretations is approximately the same.

4.10 Costs and accessibility

Costs and accessibility for SPOT data vs aerial photos were evaluated for the applications in this study.

Costs for air photos from 9 200 m are higher than for SPOT data. Air photos from 13 200 m are however less expensive than SPOT data. As an aim at the National Land Survey to develop more efficient methods for map production, digital interpretation methods are of great interest. Costs for satellite data benefit from the use of digital methods.

Accessibility factors are more difficult to compare. Both SPOT data and aerial photos should have the potential of supplying NLS with the needed data for the map revision application studied here. For SPOT data, programming demands from other customers could cause a conflict. Also, extreme weather situations, especially in the very northern parts of the country, can influence the outcome from both the SPOT satellite and from aerial photography.

5. CURRENT WORK

Current work involves evaluation of digital revision methods with SPOT data at the National Land Survey.

The geographic information system ARC/INFO is one of the digital systems used for cartographic purposes at the National Land Survey. The ARC/INFO workstation version 6.0 software allows raster images, such as satellite imagery, as a background to geographic data on the display. The satellite data can be contrast stretched to enhance certain features of current interest. The raster data is registered to the map data so each point corresponds to the same point on the ground. It is possible to zoom and move around in the images.

A future revision process using SPOT imagery could typically include the following steps: The existing digital data (clearings, roads, etc.) is displayed on the screen. Newly acquired satellite data, delivered on 1/4" cassettes, is also displayed. New features in the image is digitized using ARCEDIT and eventually used to update the objects in the database.

The described process is an available technique today at NLS, made possible through todays development in hardware and software for geographic information systems, and also because the topographic map data at NLS is digitally stored.

We believe that a future step in development of digital revision methods is semi-automatic techniques taking advantage of both the inherent automatic interpretation possibilities in digital satellite data and the inimitable capability of human decision involved in image interpretation.

6. CONCLUSIONS

This study shows that, despite differences in geometric resolution in the image materials, no differences of significance for topographic map revision are found in the interpretations of roads and clearings in air photos (9 200 meters), SPOT XS or SPOT PAN, regarding the different accuracy measures: completeness, shape and geometric accuracy. However, roads on the actual clearings have been found to cause some problems in XS.

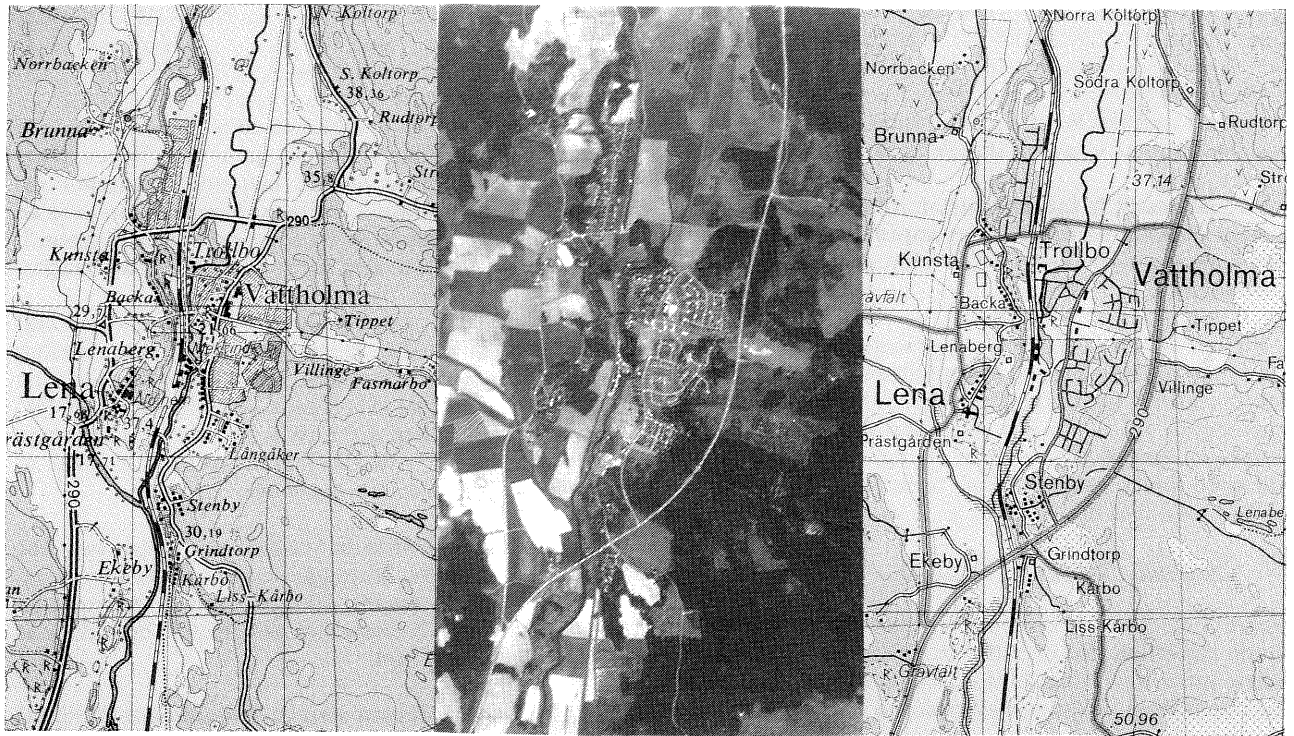
In SPOT images the delimitations of new urban areas can be interpreted while the classification into different categories of urban areas is not possible. For aerial photos the situation is much the same.

The result also indicate that training is needed to fully take advantage of the multispectral images of SPOT.

Costs for air photos from 9 200 m are higher than for SPOT data while air photos from 13 200 m are less expensive than SPOT data. However, for digital revision methods, which is likely to be used in the future, satellite data has the advantage of being in digital form.

Accessibility factors are more difficult to compare. Both SPOT data and aerial photos should have the potential of supplying NLS with the needed data for the map revision application studied here.

The conclusion of the study is that SPOT data is a useful data source, for topographic map revision at the scale of 1:50 000 in Sweden, regarding roads, clearings and built-up areas.



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Figure 2: Map revision. Part of the topographic map sheet Östhammar 12I SV, scale approximately 1:50 000. **Left:** old map, revised 1982. **Centre:** SPOT PAN 1990. **Right:** newly produced map based on aerial photos (altitude 9 200 m) from 1989 and field control in 1990.

SPOT data has not been used in the production of the new map, but it has been available as an aid. In the study, however, it has been shown that SPOT images is a useful tool for the planned future revision of this map; regarding roads, built-up areas and clearings.