Norsk Regnesentral
NORWEGIAN COMPUTING CENTER

Note

Application of satellite data in management of cultural heritage

Project Report 2009

Note no SAMBA/35/09

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Date 15 March 2010

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Front page photo

From Quickbird satellite image of Tjølling, acquired on 24 July 2009 at 10:40 AM. Two circular crop marks are clearly visible.

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Quality assurance	Rune Solberg
Date	15 March 2010
Year	2010
Publication number	SAMBA/35/09

Abstract

This report describes a prototype software system, *CultSearcher*, which is capable of detecting some previously unknown cultural heritage sites in high-resolution satellite images of agricultural land in Norway. The software detects circular patterns in the images. These patterns may be indications of destroyed and over-ploughed grave mounds. The new detections are to be verified by field inspections this summer.

The focus of the report is two-fold. Firstly, it describes improvements of the software made during 2009. This includes an improved detection algorithm, an improved user interface, and improved processing capability. Secondly, it describes soil marks and crop marks that are detected by the improved software. Many of the detections are previously unknown. Some of these are both obvious and close to known grave sites, so that they be included in the Norwegian national cultural heritage database Askeladden without further investigation. Other detections need to be confirmed by field work.

In conclusion, 2009 was a break through year in the project, by demonstrating that previously unknown cultural heritage sites can be detected by satellite remote sensing algorithms in a cost-effective manner.

Keywords	Crop marks, soil marks, Quickbird, Geometrical correction, Orthorectification, Ring edge detection
Target group	Archaeologists, remote sensing researchers.
Availability	Open
Project number	220 417 CultSearcher09
Research field	Earth observation
Number of pages	138

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1 Introduction

The increasingly intensive use and modification of the landscape resulting from modern demands for efficient infrastructure and land use (agricultural production, mining, energy sources, leisure/tourism facilities, etc.) exerts growing pressure on cultural heritage in the landscape. In order to match the political intentions of updated and sustainable cultural heritage management, it is necessary to develop a cost-effective method for locating and monitoring cultural heritage sites. In recognition of this, a project was started in 2002 with the overall aim of developing a cost-effective method for surveying and monitoring cultural heritage sites on a regional and national scale.

The early stage of the project focused on the development of automated methods, such as pattern recognition, for detecting and locating cultural heritage sites. The working assumption is that cultural heritage sites with no visual apparent manifestations above ground may be detectable in satellite images due to alterations in the spectral signature of the bare soil or of uniform vegetation growing there (crops). During the last project years the aim was to develop a software prototype, CultSearcher, to provide computerized assistance in the analysis of satellite images. In particular, the software marks possible sites for further inspection by an archaeologist.

This report describes the achievements of the project during 2009. Three major shortcomings of the CultSearcher software as of 2008 have been addressed in 2009. Firstly, improvements of the pattern recognition algorithm results in a substantial reduction in the number of false positives, while at the same time performing a meaningful ordering of the detected ring candidates, with the most probable rings at the top of the list. Secondly, the user interface has been improved so that operators can easily browse through the detected ring candidates and view meaningful ring parameters. Thirdly, a tutorial for geocorrection of the satellite images has been written. By geo-correcting an image, one is reducing the problems experienced in 2008 with agricultural masks not matching the images.

In the spring of 2009, areas for new Quickbird image acquisitions in Vestfold and Oppland counties were identified. Unfortunately, only 2 of 6 areas in Vestfold, and 0 of 2 areas in Oppland, were captured, due to heavy cloud coverage in most of the desired acquisition period. In order to process the new Vestfold images, a cloud detection and masking module was developed and integrated in CultSearcher. The new images were then fed through the production line and subsequently checked by archaeologists. For Sør-Trøndelag County, archive Quickbird images of three areas were identified and purchased. The Sør-Trøndelag images were inspected manually by archaeologists for identifying cultural heritage related crop marks and soil marks. The Vestfold images were processed by CultSearcher and then manually checked by archaeologists.

The rest of this report is organized as follows. Chapter 2 explains the improvements of the detection algorithm. The new Quickbird images are presented in Chapter 3. In Chapter 4, the results of automatic detection on the Vestfold images are described, whereas Chapter 5 describes visual inspection of the Sør-Trøndelag images. The the two next chapters shift the focus back to the software. In Chapter 6, the user interface improvements are detailed, whereas

a step-by-step geo-correction tutorial is given in Chapter 7. The report ends with concluding remarks in Chapter 8.

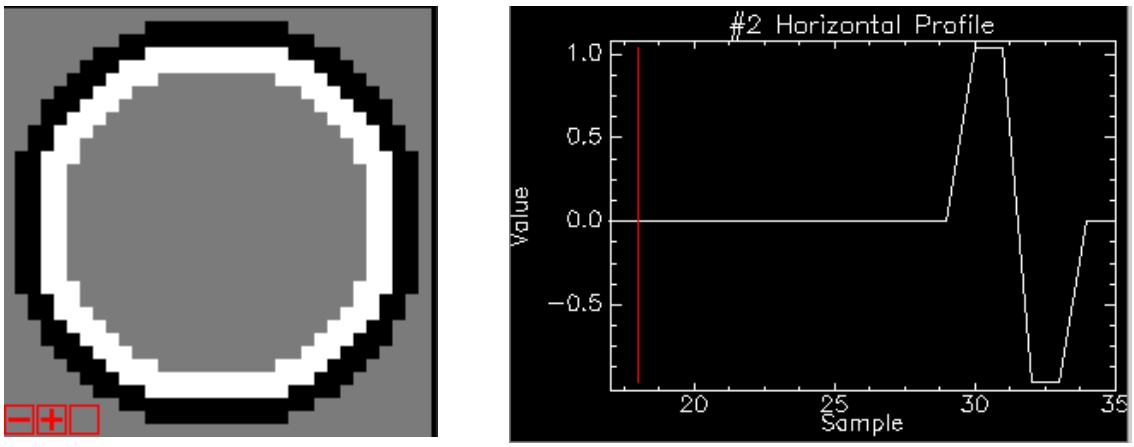
2 Improvements of automatic detection of circular soilmarks and cropmarks

In 2008, the ring detection algorithm contained the following steps.

1. Compute a locally contrast enhanced image
2. Convolve the contrast enhanced image with a ring template with radius *r*.
3. Threshold the convolved image to get ring candidates
4. Repeat steps 2-3 for different radii.

In 2009, the ring detection is a modified version of this, as follows.

1. Compute a locally contrast enhanced image
2. Convolve the contrast enhanced image with a ring edge template with radius *r*.
3. Threshold the convolved image to get ring edge candidates
4. Repeat steps 2-3 for different radii.
5. Combine ring pairs having the same center but different radii, to form *strong ring indications*. The ring pairs must be of opposite direction. For each strong ring indication, compute the distance between the ring pair centers and the difference in radii.
6. All remaining ring edges are weak ring indicators.
7. For all ring indicators, compute a number of pattern recognition features.



(a) (b)

(c) (d)

Figure 1. (a) Ring template. (b) Horizontal profile of ring edge template. (c) Small part of a Quickbird image, centered on a soil mark. (d) Detected ring edges on the soil mark.

2.1 Detection of ring edges

A ring edge template (Figure 1a) can be used to detect ring edges in entire image, by convolving the image with the template. The outside edge of a bright ring on a dark background will result in a high positive value, whereas the inside edge will result in a high negative value. For a dark ring on a bright background, the outside ring will give a high negative value, and the inside ring a high positive value.

The algorithm will use ring edge templates of different sizes. Each convolution of a ring edge template of a specific radius with the image will find ring edges of that radius. Radii in the range r_1 .. r_2 are used by default, but the user may change the minimum and maximum radii.

2.2 Detection of ring pairs

One of the strongest indications of a ring is the presence of a pair of ring edges of opposite sign, for example an outer ring going from dark to bright and an inner ring going from bright to dark.

2.3 Feature extraction

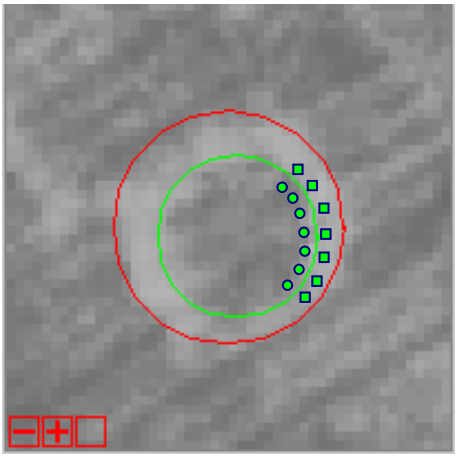


Figure 2. Pairwise sampling of pixels on both sides of a detected circular edge (green).

When a ring edge has been detected, pixel pairs on both sides of the edge are sampled and used for computing features:

- Match strength = $\frac{\#(I_2 > I_1)}{N}$
- dMPR = $\frac{|m_2 - m_1|}{\sqrt{\sigma_1^2 + \sigma_2^2}}$
- CS = $\frac{\int p_1(x)\,p_2(x)dx}{\sqrt{\int p_1^2(x)dx \int p_2^2(x)dx}}$
- Laplacian = $\frac{\int p_1(x)\,p_2(x)\,f^{-1}(x)dx}{\sqrt{\int p_1^2(x)\,f^{-1}(x)dx \int p_2^2(x)\,f^{-1}(x)dx}}$

If a matching pair of ring edges has been found, additional features are computed:

- Thickness = $r_2 - r_1$
- Offset = distance between ring edge centers = $\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$

Here, I denotes the intensity, m the mean value, σ^2 the variance, p the probability density function, r the ring radius, and (x, y) the center of a ring. The function f is the average probability density function of the inner and outer rings.

To remove false detections, thresholds are used on the computed pattern recognition features.

Then the remaining ring indicators are ordered as follows. The dMPR and Laplacian measures are normalized to the interval [0,1], where 1 is the highest score and 0 the lowest. Then, a rank-measure is created by computing the Euclidean length of the *normalized* dMPR and Laplacian measures, i.e.

- rank Measure = $\sqrt{dMPR_{norm}^2 + Laplacian_{norm}^2}$

In order to rank double rings on top of the list, a constant equal to 100 is added to the rankMeasrure for double rings.

2.4 Ring detection results

The detection algorithm was run on the training data. This will most likely give an optimistic estimate of the performance. Further, this was compared with the performance of the algorithm from 2008. The test images contained 22 visible rings in total, and the detection results for each ring (Figure 3 – Figure 13) as well as the number of false detections was compared with the algorithm of 2008 (Table 1). The performance of the algorithm can be adjusted by a single threshold value on an overall score value, increasing (decreasing) the number of true detections, with the effect that an increasing (decreasing) number of false detections are also being made. Compared with the 2008 algorithm, the number of false detections was reduced from 174 to 24 when the thresholds were set so that 15 rings were detected (Table 1).

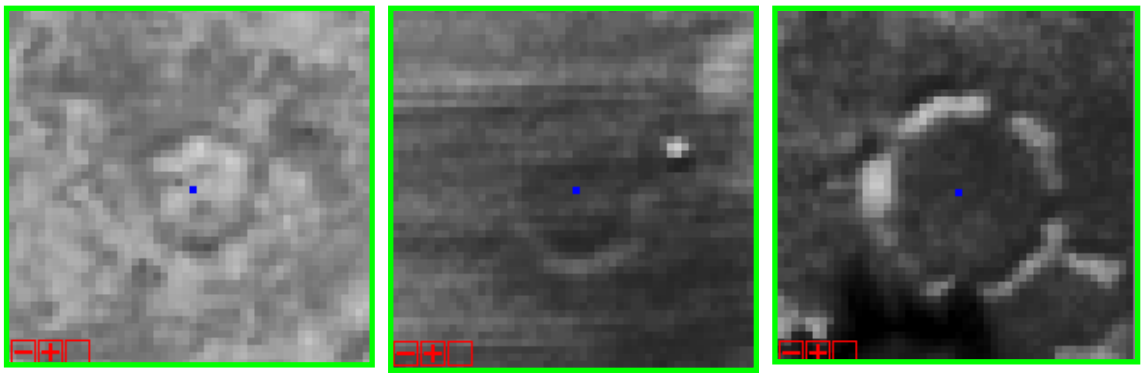


Figure 3. Rings in the Gardermoen sub1 image, detected as double ring edges.

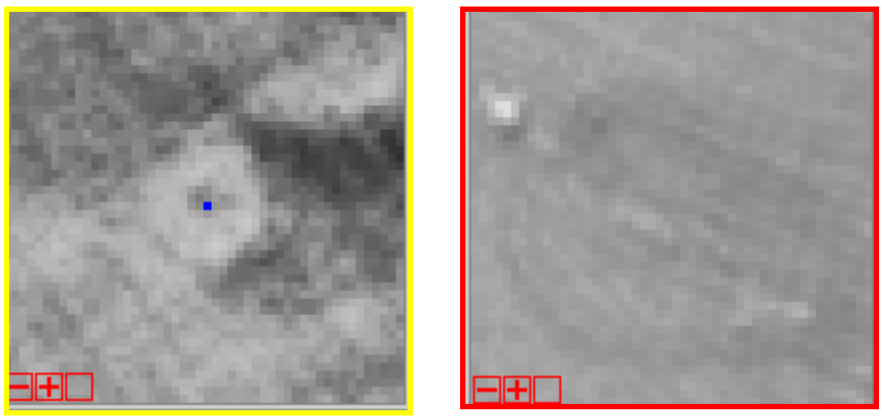


Figure 4. Left: Detected as a single ring edge. Right: not detected.

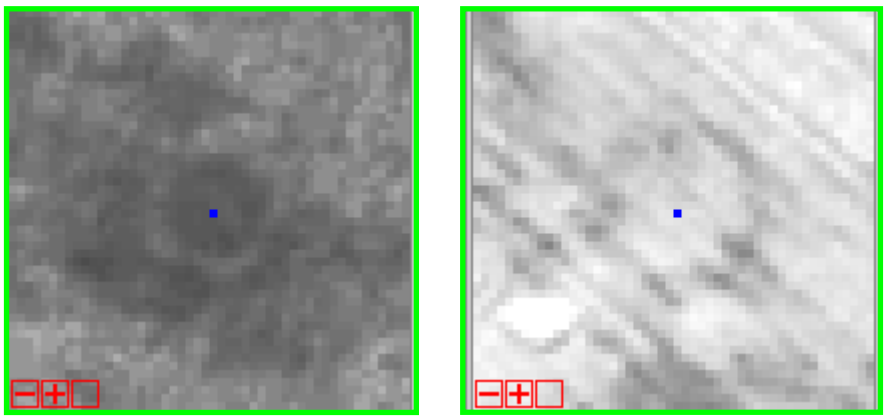


Figure 5. Rings in the Gardermoen sub 2 image detected as double rings.

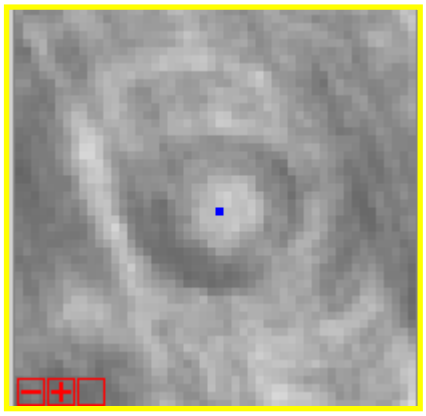


Figure 6. Ring in the gardermoen sub3 image detected as a single ring edge.

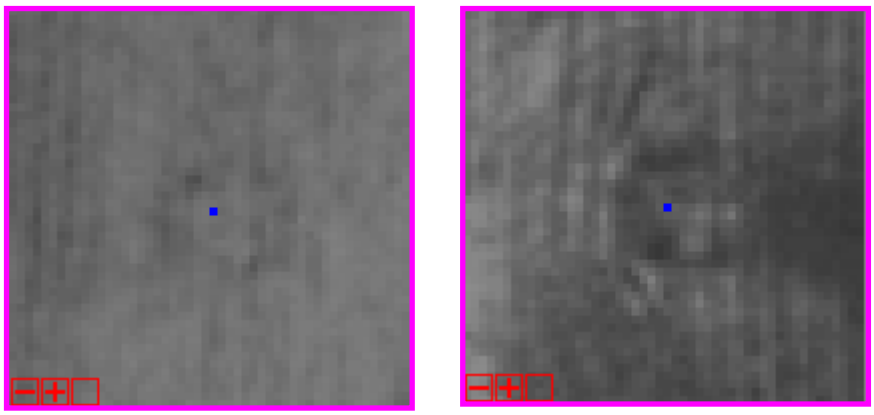


Figure 7. Rings not detected in the Gardermoen sub3 image. However, by lowering the thresholds, these could be detected, but with a higher number of false detections.

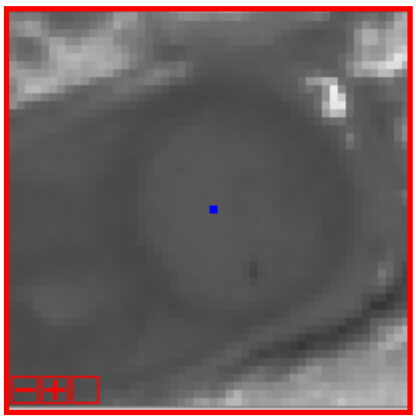


Figure 8. A ring in the Gardermoen sub 3 image that was not detected.

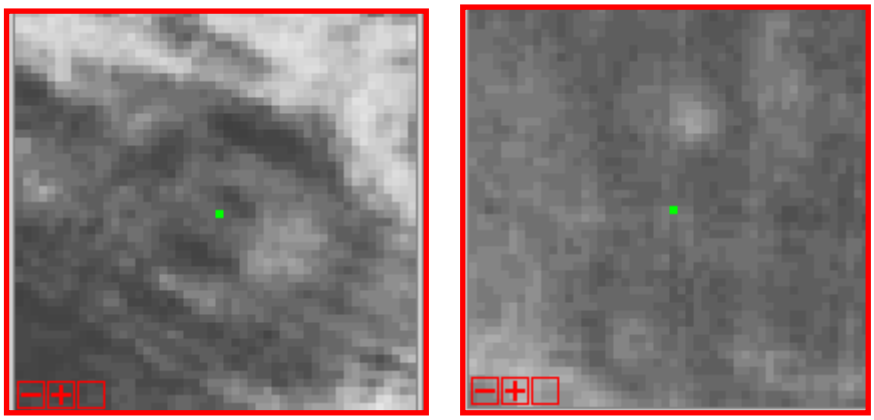


Figure 9. Rings in the Gardermoen sub 4 image that were not detected.

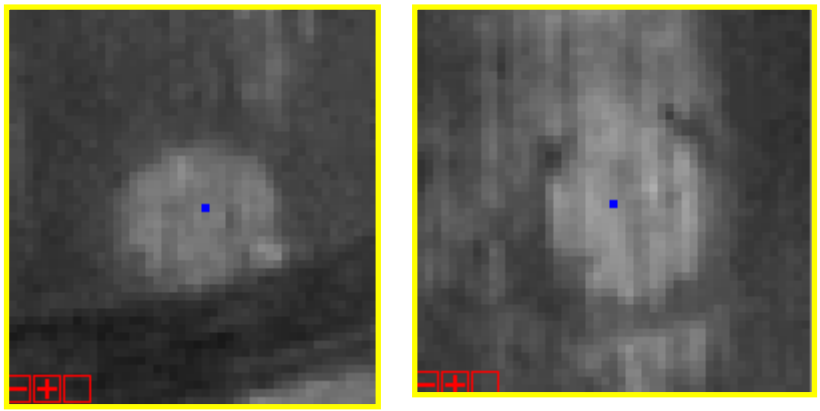


Figure 10. Rings in the Lågen sub1 image that were detected as single ring edges.

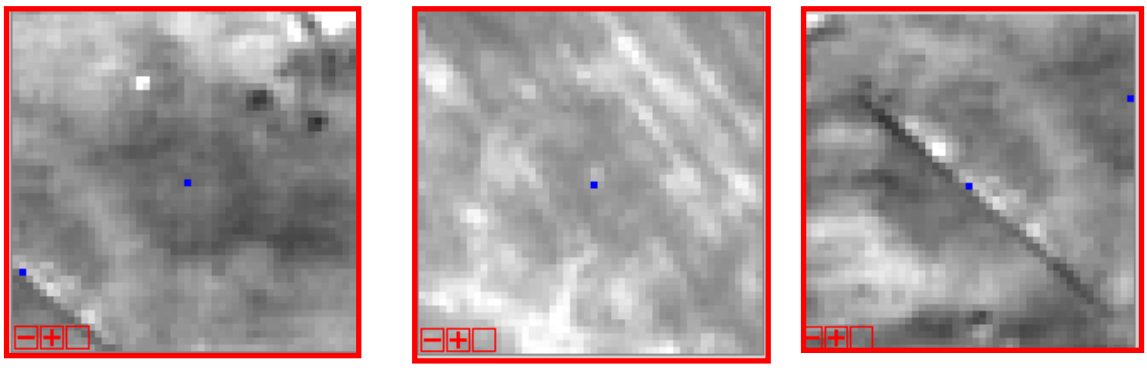


Figure 11. Rings in the Lågen sub1 image that were not detected.

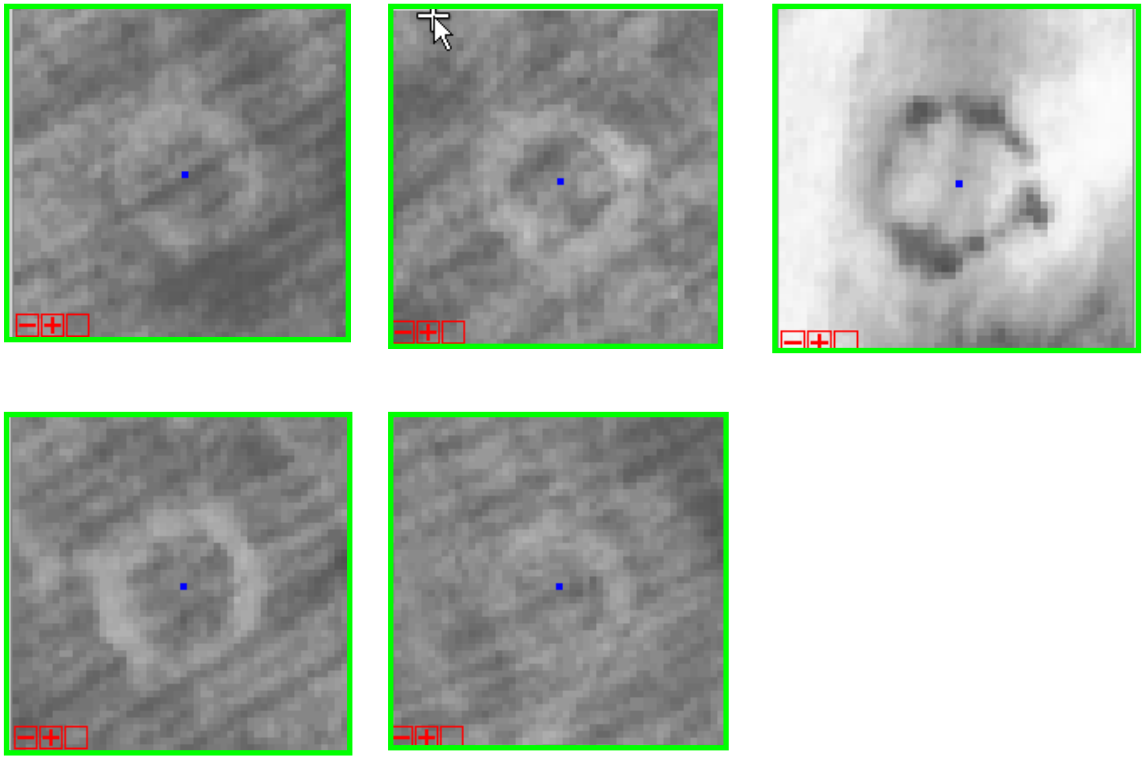


Figure 12. Rings in the Lågen sub3 image that were detected as double ring edges.

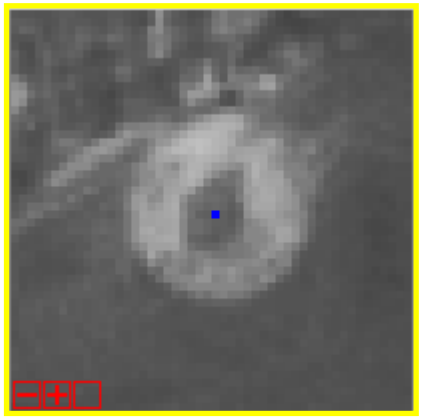


Figure 13. A ring in the Lågen sub 3 image that is detected as a single ring edge.

Table 1. Detection results for the 2008 algorithm and the new 2009 algorithm.

Method	Detection type	Gardermoen									Lågen		Total
		sub1a	sub1b	sub1c	sub2a	sub2b	sub3a	sub3b	sub4a	sub4b	sub1	sub3	
	true rings	2	1	2	2	0	3	1	0	0	5	6	22
2008-a	true det	0	0	1	1	1	2	1	1	0	2	6	15
	false det	11	9	1	8	12	10	7	8	20	46	42	174
2008-b	true det	0	0	1	1	1	1	1	1	0	1	5	12
	false det	1	1	0	1	2	1	1	1	4	12	7	31
2009	true double	2	0	1	2	0	0	0	0	0	0	5	10
	false double	0	0	1	1	1	0	0	0	2	0	0	5
	true single	0	1	0	0	0	1	0	0	0	2	1	5
	false single	0	2	1	1	3	0	0	2	1	5	4	19
	order single		1				1				2, 4	2	
	sum true	2	1	1	2	0	1	0	0	0	2	6	15
	sum false	0	2	2	2	4	0	0	2	3	5	4	24

2.5 Remaining challenges

The number of false detections is high in fields with regularly spaced stripes from tractor, as the stripe distance may coincide with one of the ring edge filter diameters. Then, only a little extra noise can create false ring detections, especially at locations where tractors have turned. The stripe patterns may be detected by using texture information. However, this problem is reduced compared with 2008 results.

There could be an even better ordering of single ring edge detections. The features could be modeled statistically and ordered based on probabilities. At the moment, the ordering is quite meaningful, listing the true detections quite early in the list. Still, some true rings are listed after several false ring detections.

There is little data for validation. Agricultural masks are needed for new images, and more images are needed. We plan to order more images in 2010

Cloud detection might be needed. The 2009 images from Vestfold have many clouds. A cloud detection algorithm could be used. However, no cloud detection was used when processing the

Tjølling image, permitting the algorithm to adjust the contrast and intensity in light cloud areas so that rings could be detected there as well.

3 New satellite data

One of the experiences from the 2008 project was that Ikonos images, of 1.0 m resolution, were of slightly too low resolution for successful detection of ring structures that could be cultural heritage sites. So for 2009, it was decided to concentrate on Quickbird images, of 0.6 m resolution.

For Sør-Trøndelag, three areas that had archive Quickbird images that could contain crop marks or soil marks of archaeological sites, were identified, and the images were ordered. For these images, a visual inspection was performed by experienced archaeologists. The results were several new archaeological sites. A detailed description is given below in Chapter 5.

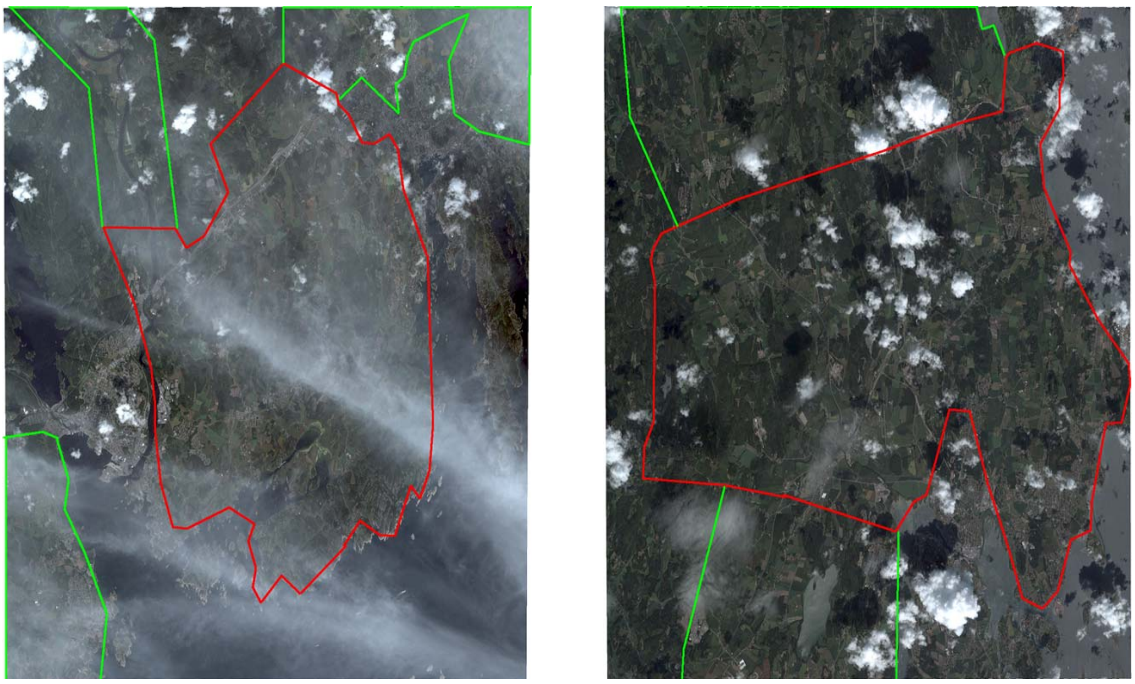
For Oppland, two areas were identified for ordering of new Quickbird images acquisitions in July/August. Unfortunately, none of these were actually acquired due to heavy cloud cover on the possible dates for acquisitions.

Figure 14. The Quickbird image of an area northwest of Tønsberg, acquired on 16 July 2009 at 10:50 AM.

For Vestfold, six areas were identified for ordering of new Quickbird images acquisitions in July/August. Two of these had successful acquisitions, although with some cloud cover, obscuring parts of the scene. In addition, parts of the other four areas were partially inside the acquired 16.5 x 16.5 km2 images (Figure 16), and the parts covered by the 24 July 2009 acquisition were ordered as archive images in December 2009 (Figure 17).

For the results of the processing of the new Vestfold images and subsequent manual inspection, see Chapter 4 below. For the manual inspection of the Sør-Trøndelag images, see Chapter 5 below.

Figure 15. The Quickbird image of Tjølling, acquired on 24 July 2009 at 10:40 AM.



(a) (b)

Figure 16. The full Quickbird scenes. (a) This scene covers the Tjølling area, and parts of the Brulanes, Lågendalen and Sandefjord areas. (b) This scene covers the Tønsberg area, and parts of the Sandefjord and Horten areas.

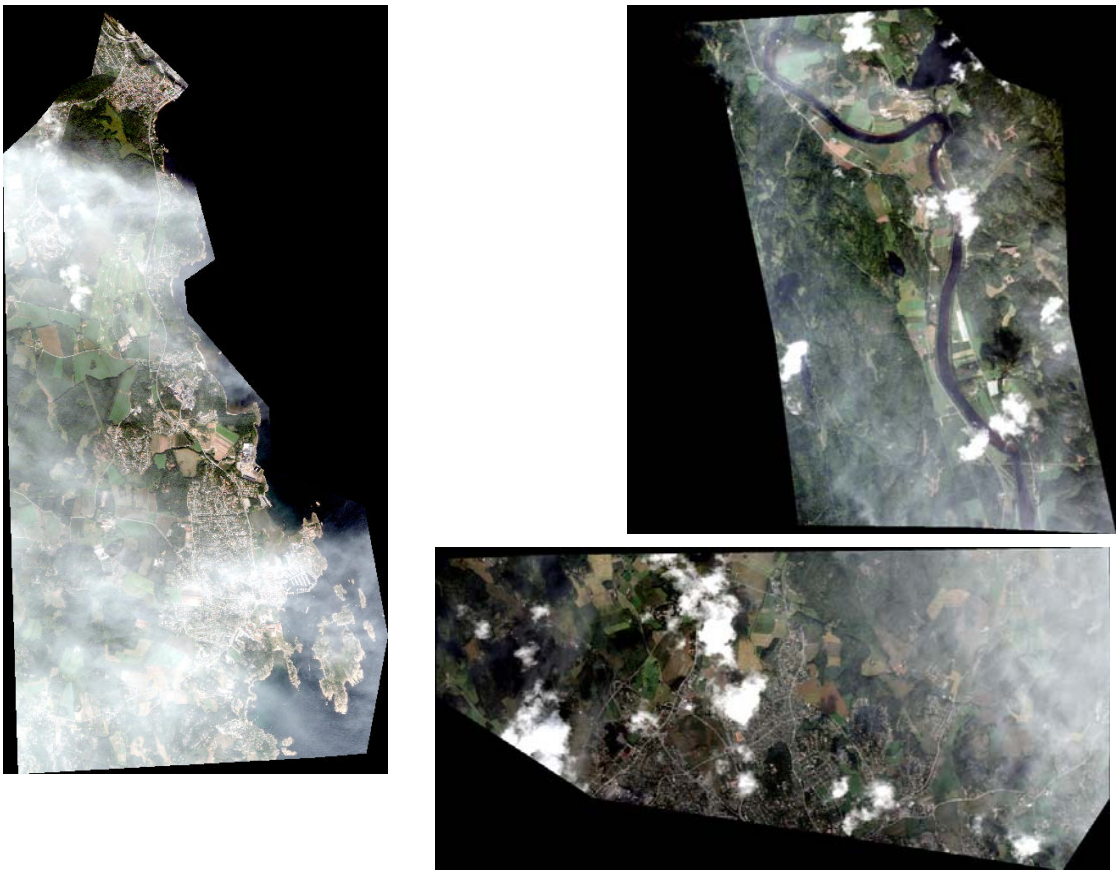


Figure 17. Additional images. Left: Stavern, top right: Hedrum, bottom right: Sandefjord. All images are from the same 24 July 2009 acquisition as the Tjølling image.

4 Automatic detection of cultural heritage sites in new Vestfold images

4.1 Tjølling

4.1.1 Visual inspection Cultsearcher detetctions in the Tjølling image at NR, November 2009.

Table 2. CultSearcher detections in the Tjølling image. These have been automatically detected and then confirmed by visual inspection of the image by archaeologists, guided by CultSearcher.

CultSearcher detection no	UTM zone 32 east	north	Farm name	Comment
1	563130	6545973	Valby	Within known site
2	563116	6546009	Valby	Within known site
3	568639	6553536	Brønnum	Not previously registered. Close to intact grave mounds
4	569592	6544748	Fjellvik	Not previously registered.
9	564665	6552586	Ringdal	Not previously registered.
17	565407	6546735	Løve	Not previously registered. Close to intact grave mounds in the forests on both sides
20	567730	6546527	Nedre Klåstad	Not previously registered. Visible in orthophoto of 15 July 2002.
35	567708	6550296	Hybbestad	Possible site. Not previously registered.
44	565487	6548429	?	Possible site. Not previously registered. Grave mouns both to the north and to the south

The new version of CultSearcher vas run on the entire Tjølling image. This resulted in 311 detections in total. The 50 or so strongest detections were examined jointly by Lars Gustavsen, Christer Tonning, Trude Aga Brun and Øivind Due Trier during a meeting on Monday, 16 November 2009, resulting in five clear indications of previously unknown grave mound remains, two uncertain indications of the same, and two very clear indications within an already known site for grave mound remains (Table 2). One of the new detections was also visible on an aerial photo of 15 July 2002.

Figure 18. Two very clear crop marks, located within an already registered site for traces of destroyed grave mounds. The two rings are enlarged in the insets.

Figure 19. One clear crop mark at Brønnum that was detected by CultSearcher, and a smaller one just south of it. Both appear in the inset. These are not previously regitered. They are located close to known intact grave mounds.

Figure 20. A distinct ring mark near Fjellvik. This ring mark is previously not registered.

Figure 21. A new detection near Ringdal, not previously registered.

Figure 22. This previously not registered ring mark is located between two forests containing intact grave mounds.

Figure 23. This distinct crop mark at Nedre Klåstad is also visible on an orthophoto from 15 July 2002. The crop mark is, however, not previously registered. There are intact grave mounds located a little to the north west.

Figure 24. A possible indication of a destroyed grave mound at Hybbestad or Oksholmen. This weak ring may also indicate something else. There is no cultural heritage site registered here.

Figure 25. The weak ring mark is a possible indication of a destroyed grave mound, which is previously not registered. There are known grave mound sites both to the north and to the south of this. There is a substantial amount of haze in the picture here, but still CultSearcher is able to make the detection.

4.1.2 Testing Cultsearcher Vestfold County Council –workflow march 2010.

Proceedings for validating the detections done by Cultsearcher in the Tjølling image has been approached slightly different at NIKU and Vestfold Countu Council VCC. At VCC the interpretation of the true and false detections has been recorded in a MS Access database for further investigation, and fine tuning of Cultsearcher. This in order to avoid the vast number of false detections at a later stage in the project. In the database we have noted for each detection the radius of the detection, the applied ring filter and a short interpretation of the positive or negative detection. Parallel to recording attribute data in the ms access database, we also checked detections up against the Norwegian national cultural heritage database Askeladden, and relevant archived orthophotos at the public site Norge i bilder (www.norgeibilder.no). Included work on this report this amounted VCC's workload to 18 days in total for the Tjølling image.

4.1.3 Positive detections

4.1.3.1 Detection 1 and 2 , Site Valby . Gbnr 1027/2, Larvik Municipality N 6545972.654 E 563131.478

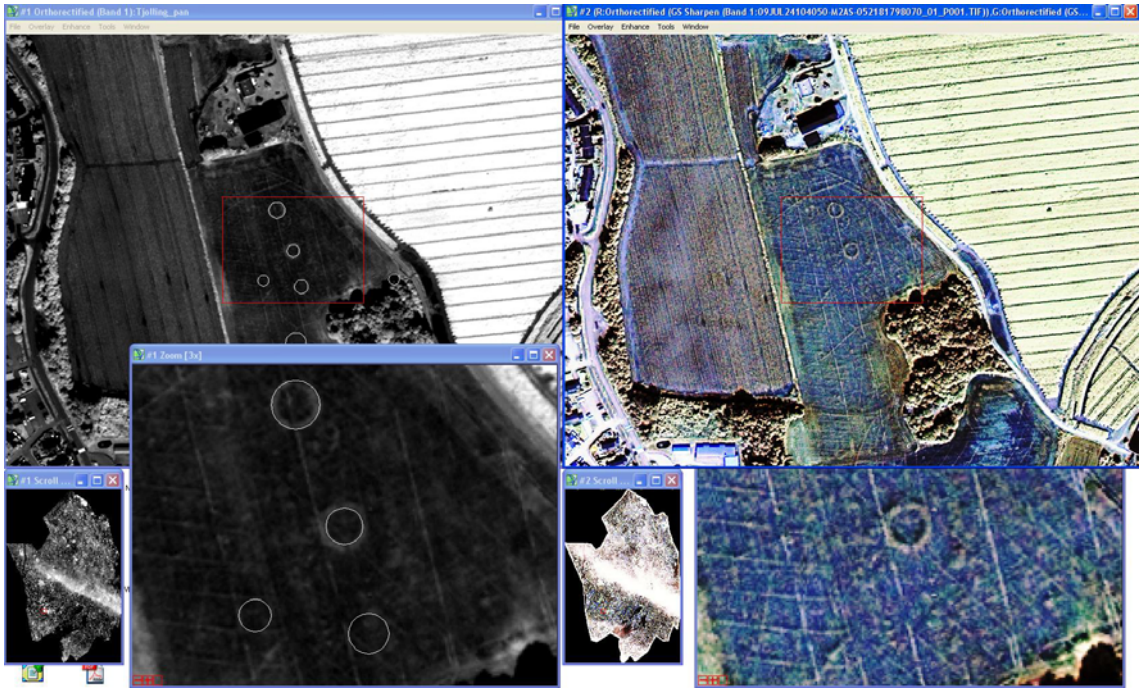


Figure 26. CultSearcher detections Nos. 1 and 2 in the Tjølling image. In the left image, two additional detections are indicated. In the right image, detections 1 (south) and 2 (north) are clearly visible.

This is a very distinguishable detection and shows two ring ditches (Figure 26), originally surrounding a grave mound, which is deleted. South of these two detections, a previously registered grave field is still present in the forest patch (Askeladden ID 94320). Detection No. 1 (southernmost) has probably been detected previously on photographs in 2005 by archaeologist Steinar Kristensen, with the following description in Norwegian:

> ***"Beskrivelse:***
> *Vegetasjonsmerker i åker. Ved analyse av flyfoto kan det i åkeren syd for Valby, 1027/2, og vest for veien til Guri, ses minst et vegetasjonsmerke i form av en ring i åkeren. Det er trolig er fotgrøften fra en overpløyd gravhaug. Nicolaysen registrerte 10 hauger der i 1867, mens Ballestad bekreftet at det hadde vært hauger der tidligere (Grieg 1943:470). Ved åkervandring i området ble en blå glassperle og to flintavslag funnet.*
>
> ***Terrengbeskrivelse:***
> *Flatt jorde. Lokaliteten ligger øst på en nordsyd-gående slette vest for Guri og Valby, på brinken, der sletten faller av mot Guribekken.*
>
> ***Orientering:***
> *Stedet ligger nord for åkerholmen, Olla, ID38694, med 8 gravhauger. Observasjon ligger omlag 125 m sør for tunet på Valby 1027/2. "* (Kristensen in Askeladden)

Detection 2 is new and not previously described, and will be included in the Askeladden database. This site was subject for investigation in the project in 2008 using Ikonos images

(Solberg et al., 2009), but at that time no ring ditches were observed, neither by visual inspection nor by using CultSearcher.

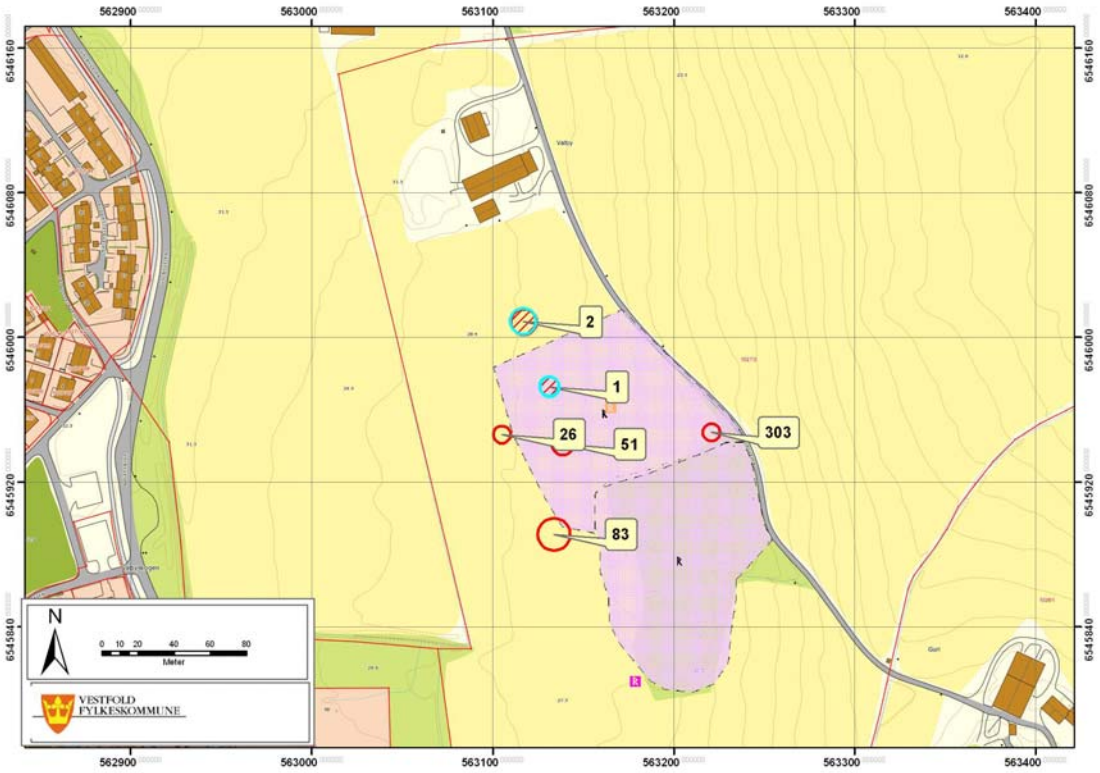


Figure 27. CultSearcher detections Nos. 1, 2, 26, 51, 83, and 303 superimposed on a map with a known grave field in pink.

4.1.3.2 Detection 3 at site Brønnum in Sandefjord, Gbnr 125/4 Sandefjord Municipality N 6544748.054 E 569592.878

Figure 28. CultSearcher detection No. 3 in the Tjølling image.

This is a site not previously known. Detection 3 (Figure 28) is approximately 10 meters in diameter and shows a distinct ring ditch. South of detection 1, a more blurry ring ditch is observable. This ring ditch was not detected in CultSearcher. In the Quickbird image it seems like the two over-ploughed graves have been connected with a bridge, a well known feature at grave fields in Vestfold County. Detection 3 is situated between two known archaeological sites, 140 meters west by southwest lies the site with Askeladden ID 19833. This site consists of two grave cairns. 65 meters southeast from detection 3, the site with Askeladden ID 75402 is located, consisting of two grave cairns.

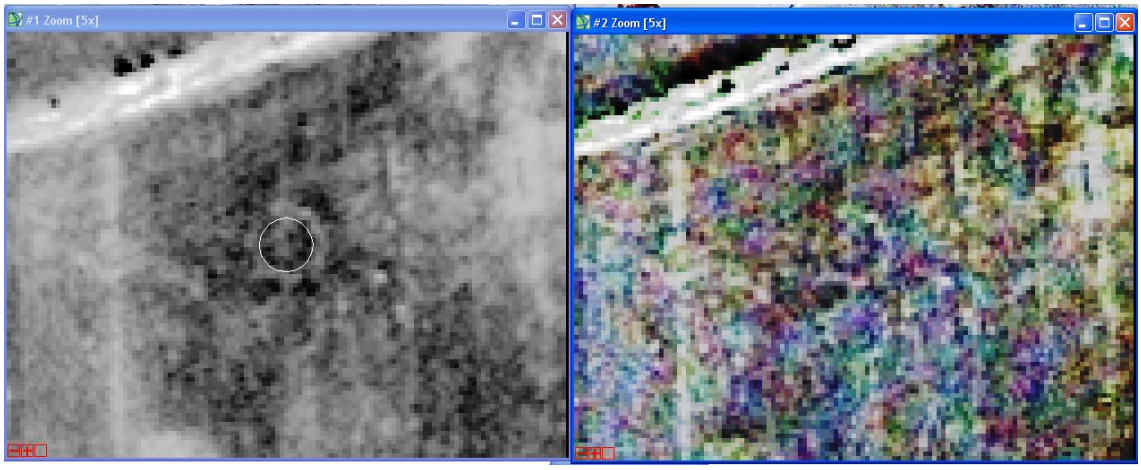


Figure 29. Detailed view of detection 3, showing a new over ploughed grave mound south of and connected with detection 3.

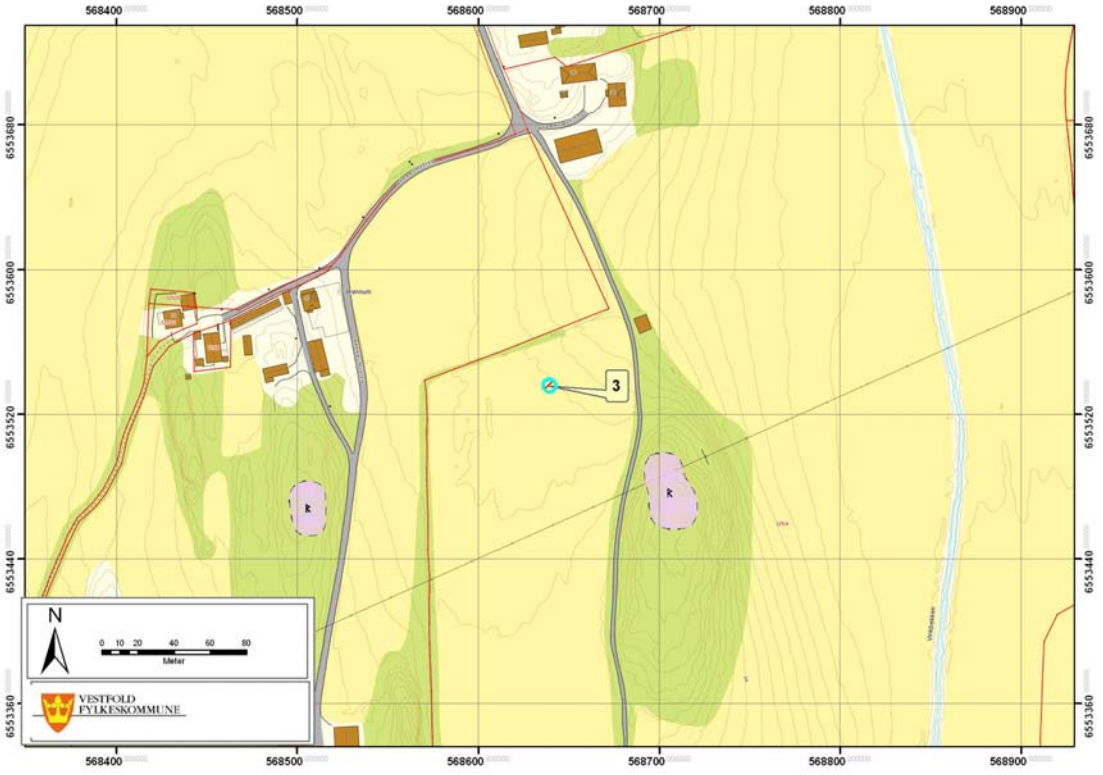


Figure 30. CultSearcher detection No. 3 in the Tjølling image, with two intact grave mounds in pink.

4.1.3.3 Detection 4 at site Fjellvik Gbnr. 1106/1 Sandefjord Municipality. N 6544748.054 E 569592.878.

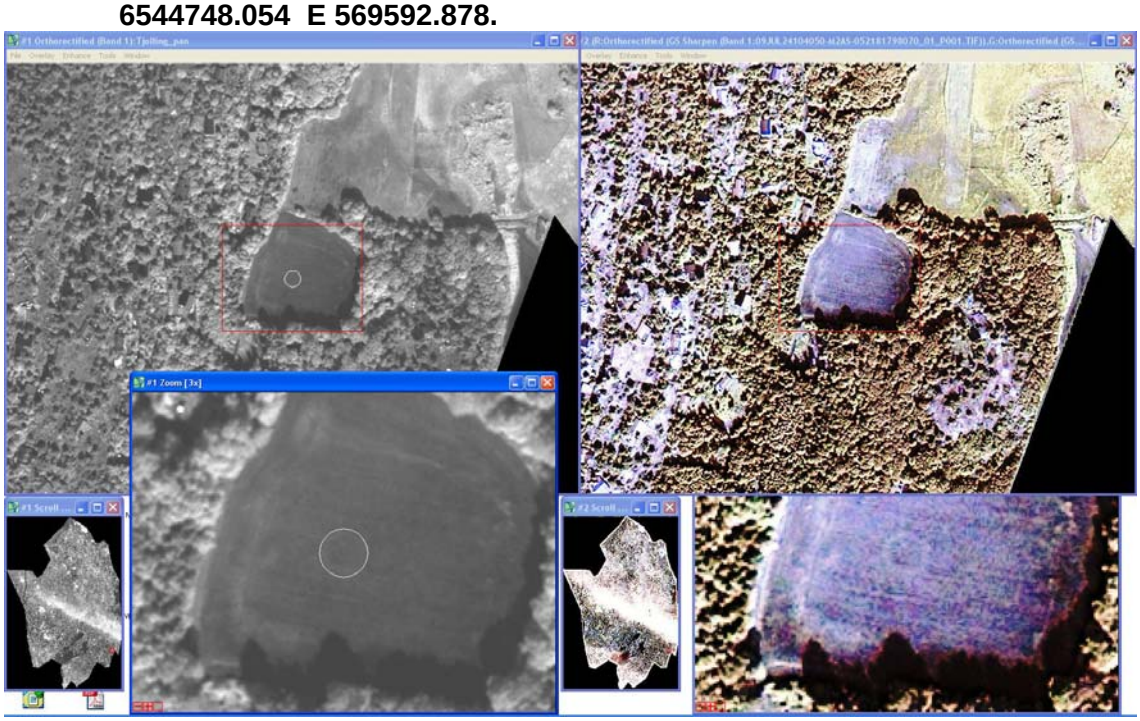
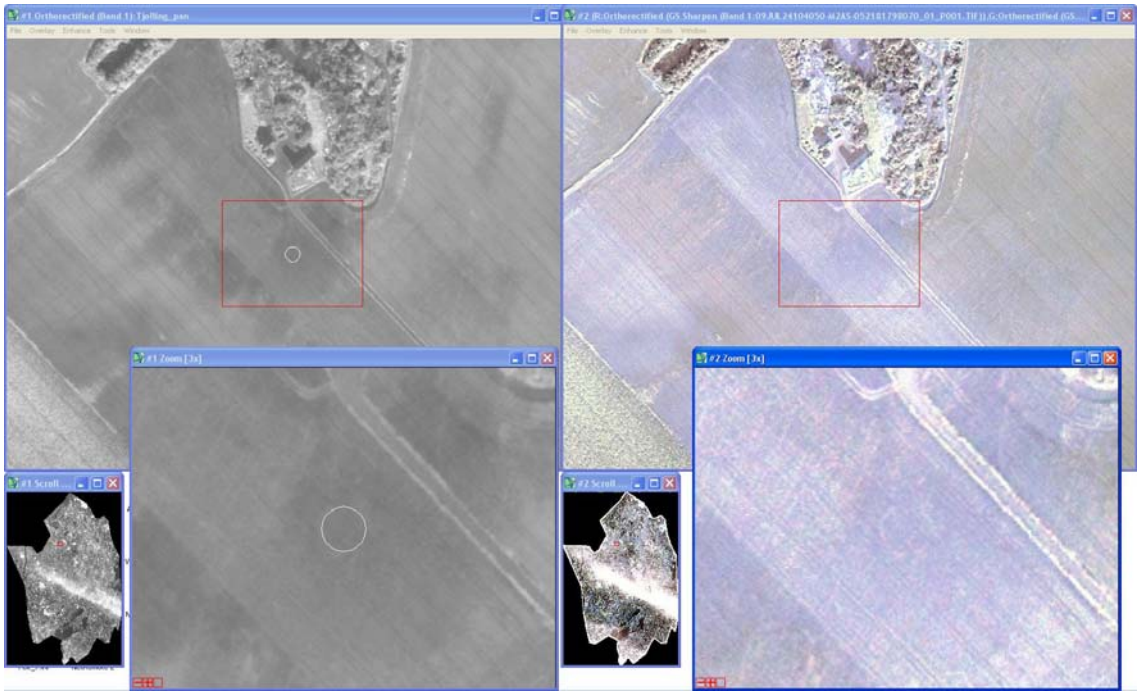


Figure 31. CultSearcher detection No. 4 in the Tjølling image.

This detection is approximately 14 meters in diameter, situated in the middle of a field surrounded by forest to the west, south, east and partly to the north. This odd placement of a grave mound needs to be investigated further with field inspections. In the Askeladden database there are no cultural heritage records at this location or close by. If, after field inspection, this site proves to be an actual cultural heritage site, it will be included in the Askeladden databse.

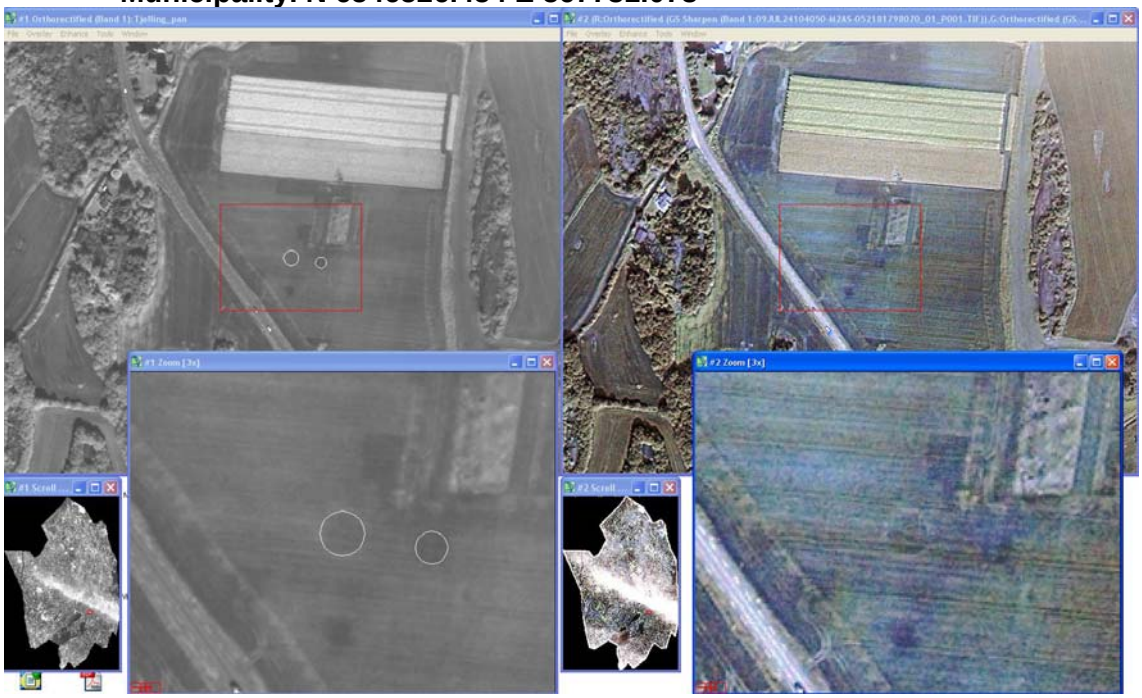
Figure 32. For CultSearcher detection No. 4 there are no known cultural heritage sites close by.

4.1.3.4 Detection 9 at site Engehågan, gbnr 141/1 Sandefjord Municipality. N 6552585.854 E 564665.678

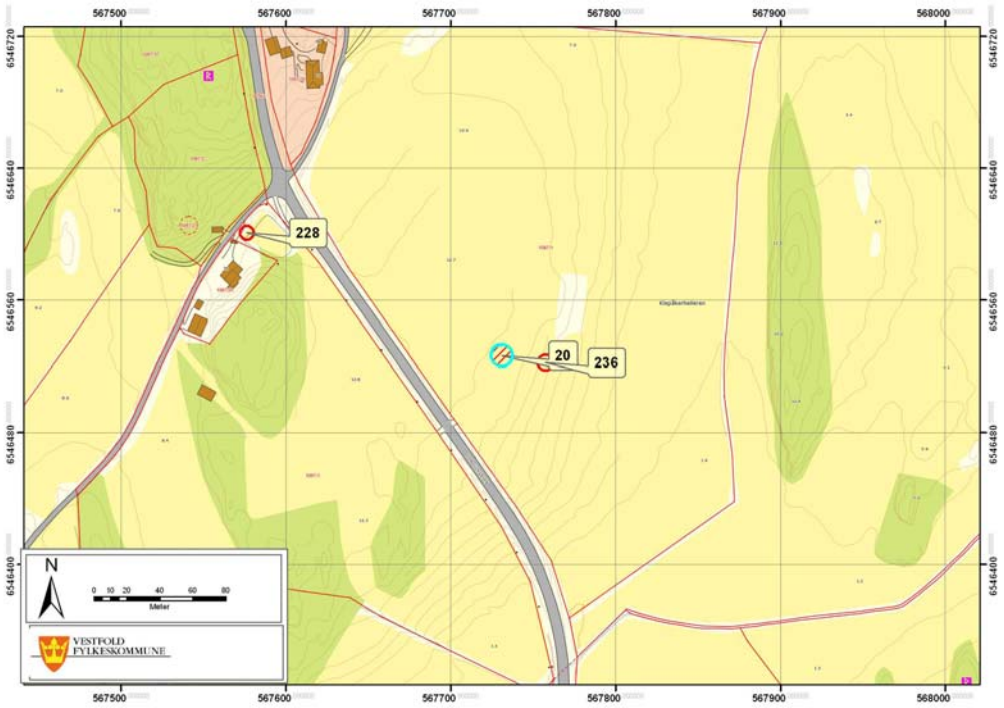


Weak detection, but probably an overplown ringditch. We have no information in our databases about this site, or about surrounding sites. This site should be investigated further before adjoining in Askeladden.

4.1.3.5 Detection 20 and 236 at site Klepåkerhelleren Gbnr 1087, Larvik Municipality. N 6546526.454 E 567731.078



A very clear detection (20), approximately 15 meters in diameter. The other detection 236 is more fuzzy and uncertain as a positive detection, this is approximately 10 meters in diameter. We have no further information in our databases concerning this site, or close nearby. In addition 7 meters south of detection 20 an undetected and more uncertain cropmark is situated, this could also be crop subjected to wind/rain . Detection 20 will be adjoined in Askeladden, detection 236 and area south of these will need further investigation before adjoining.



4.1.3.6 Detection 164 at site Nordre Kaupang. Gbnr 1029/3 Larvik Municipality N 6544815.254 E 563555.078

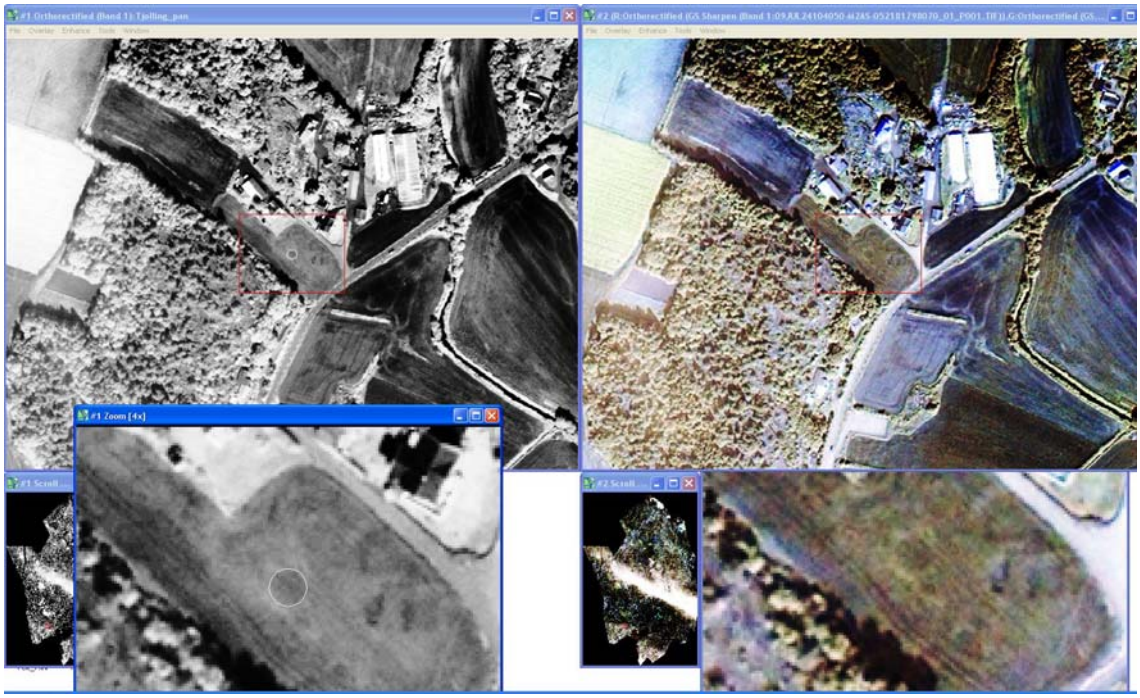


Figure 33. CultSearcher's detection No. 164 in the Tjølling image.

This detection is very clear and certain in the satellite image (Figure 33). This ring is not previously known before. Detection 164 lies in connection with the well known Viking Trading place/town of Kaupang. South of detection 164 the town site is situated. Surrounding Kaupang massive grave fields has been dug out by both amateurs and professional archaeologists over a long period in time. The largest documented gravesite on Kaupang was excavated by archaeologist Nicolay Nicolaysen in 1867, and was situated southeast of detection 164 (Figure 35). Stretching out over a kilometre in length this is one of the largest of known gravefields in Norway. Today, only fragments of this grave field is left, primarily at Bikjholberget and Lamøya.

Detection 164 lies within ID 96129, but is not described on Nicolaysen's drawings of the grave field (Figure 34).

Figure 34. Top: detection No. 164 and other detections in the vicinity. Bottom: Detection No. 164 is located inside a known grave field, but the particular ring is not previously known.

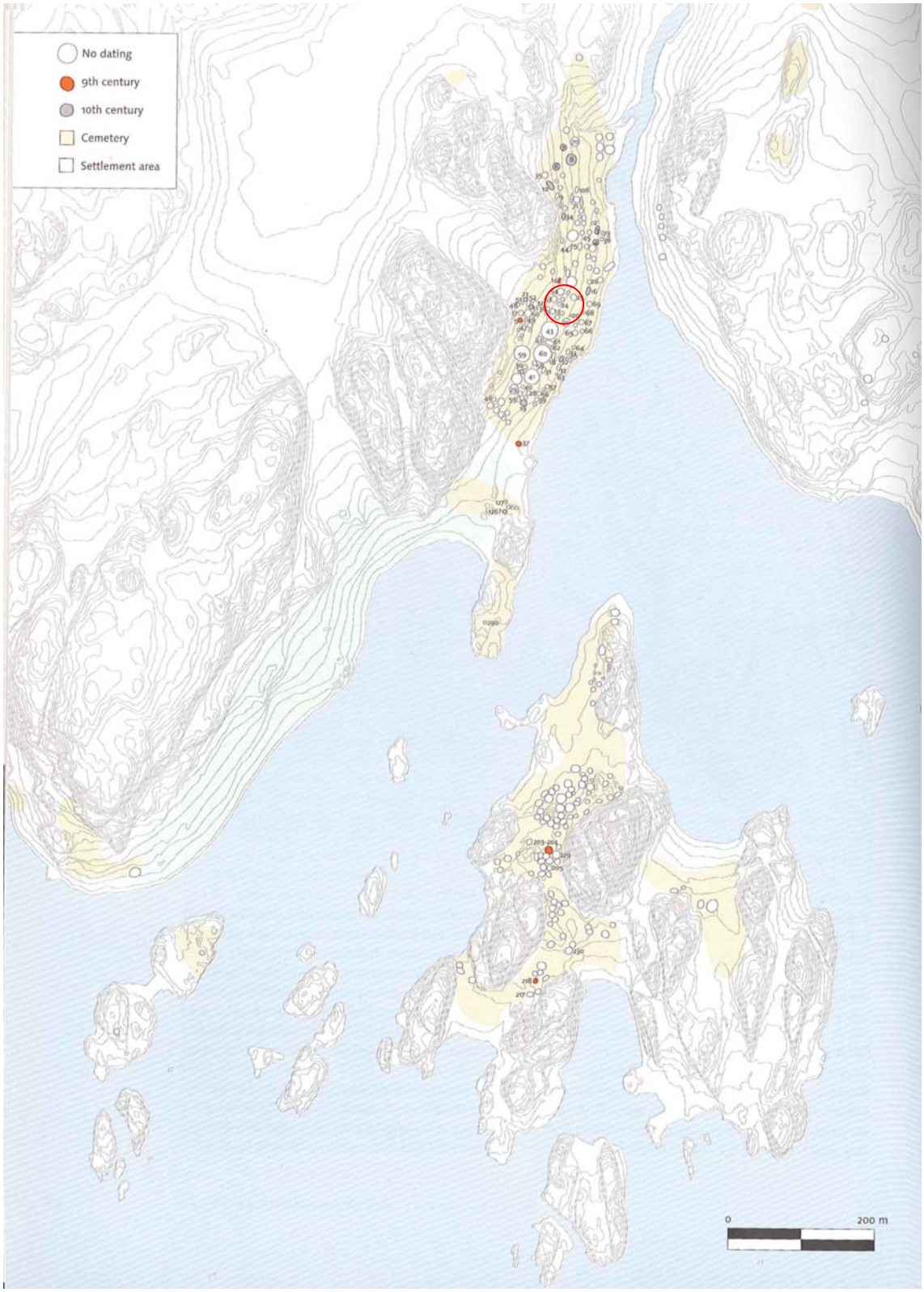


Figure 35. A map of a reconstruction of the massive gravefields at Kaupang. The red circle indicates the approximate position of detection 164. (Map from Skre et al 2006:76)

4.1.3.7 Detection 307 at site Virik. Gbnr 121/35, Sandefjord Municipality. N 6554550.854 E 568855.478

Figure 36. CultSearcher detection No. 307 in the Tjølling image.

Detection 307 is a known site which was also addressed in the project in 2008. The ring was visually observed during attempts with Cultsearcher on Ikonos images. However, Cultsearcher did not detect the ring then. Detection 307 falls within the site with Askeladden ID 9990, which was first discovered by archaeologist Per Haavaldsen in the 1970's, and has been the object for archaeological excavations in 2008 and 2009. This ring is therefore confirmed by airplane, archaeologists in the field and by Cultsearcher in a satellite image.

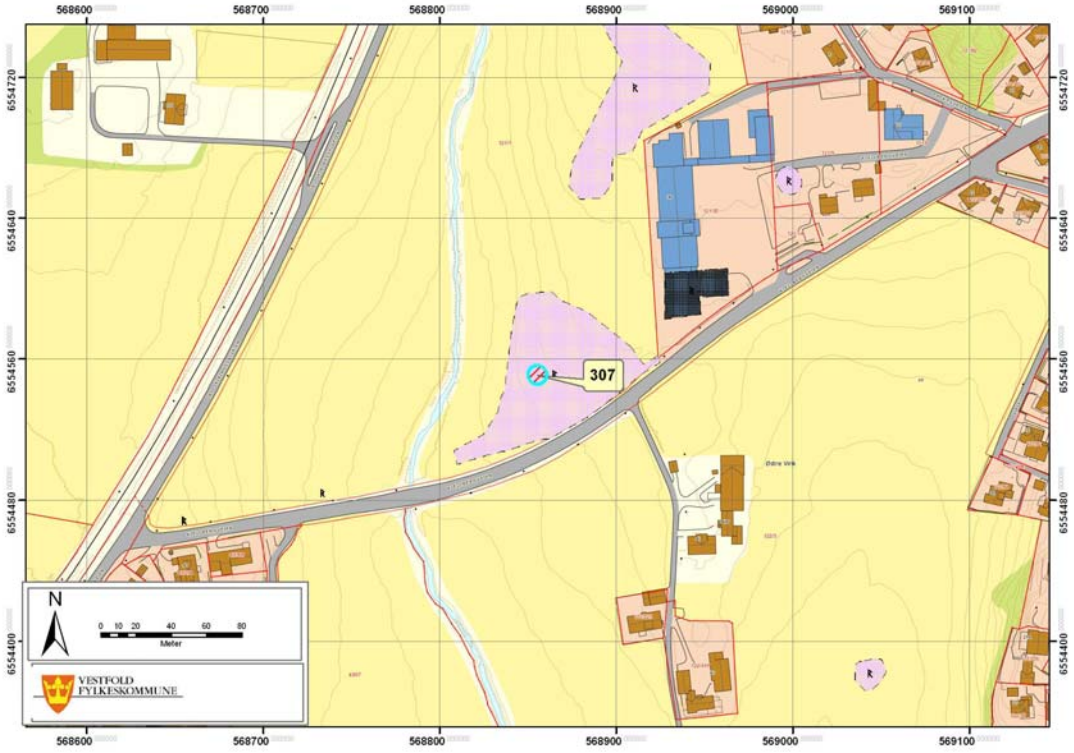


Figure 37. CultSearcher detection No. 307 in the Tjølling image is a previously known ring ditch, and is located inside a known grave field.

4.1.4 Examples of possible/uncertain detections by Cultsearcher.

In addition to the certain detections addressed in chapter 4.1.2, Cultsearcher has detected 3 more sites, where the circumstances are more difficult to interpret. These will be addressed here.

4.1.4.1 Detection 17, site Høivik. Gbnr 153/14 Sandefjord Municipality. N 6546735.254 E 565407.278

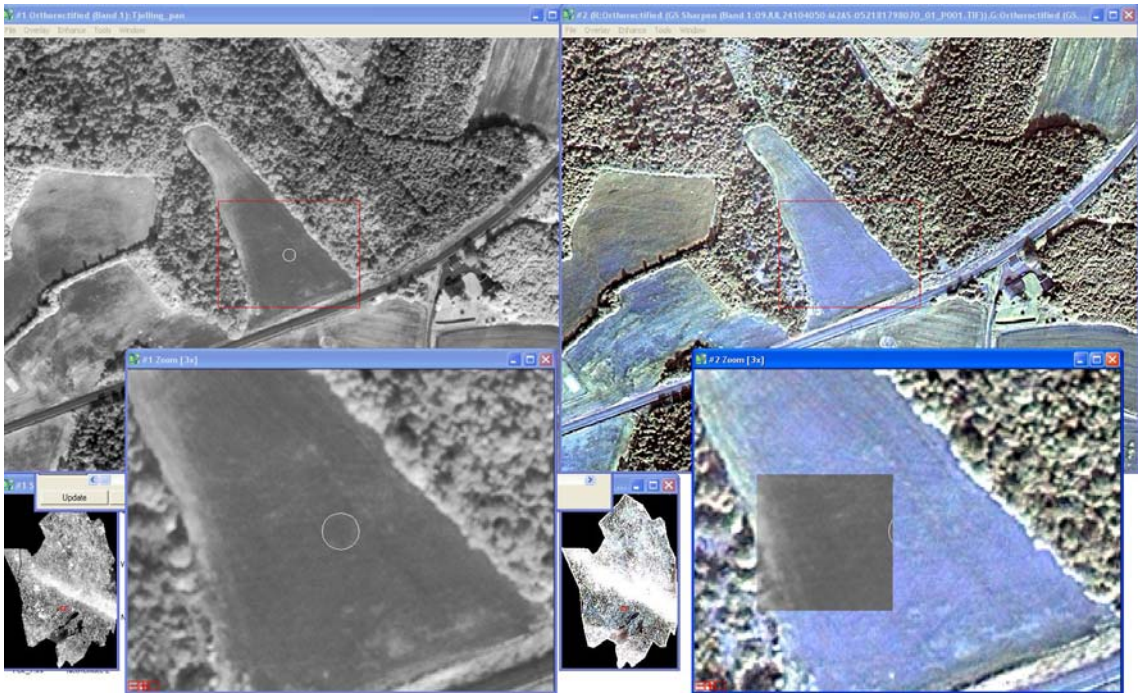


Figure 38. CultSearcher detection No. 17 in the Tjølling image.

This is a very weak ring pattern, which is approximately 9.5 meters in diameter. This site needs to be checked out more thoroughly in the field, before including the site in Askeladden. Detection 17 (Figure 39) is located in a landscape densely populated by cultural heritage sites. Both to the west (Askeladden ID 68440) and northeast (AskeladdenID 29151) of detection 17, registered grave mounds are located, near Tjøllingvolden.

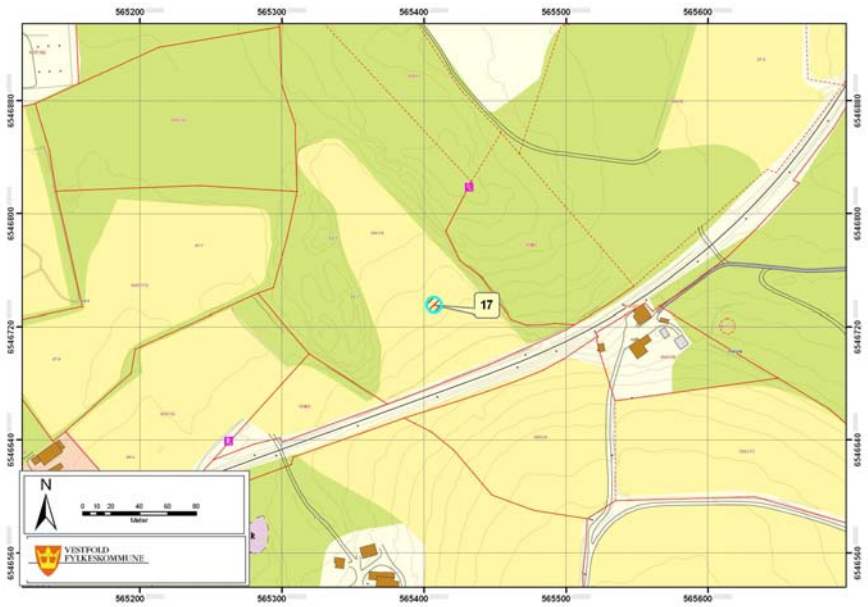


Figure 39. The location of CultSearcher detection No. 17.

4.1.4.2 Detection 35, site Hybbestad Søndre. Gbnr. 1077/1. Larvik Municipality N 6550295.654 E 567708.878

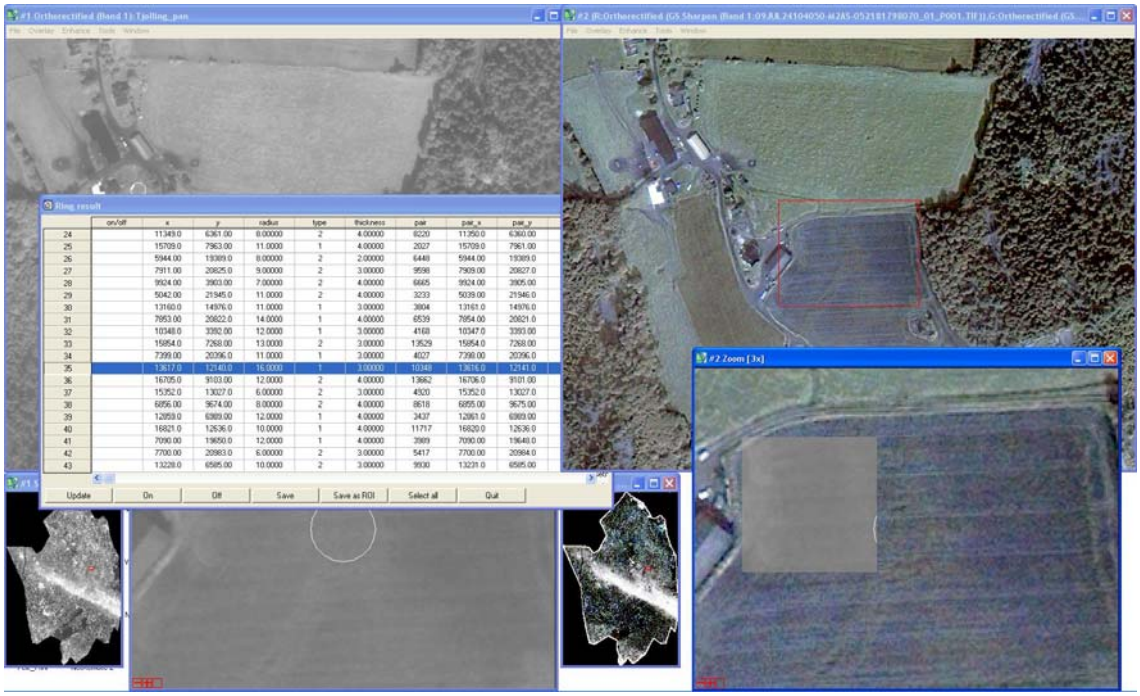


Figure 40. CultSearcher detection No. 35 in the Tjølling image.

This is a very weak detection (Figure 40), but by enhancing image with Gaussian filter, a ring is clearly conceivable. Further investigations in the field must be undertaken before detection 35 is included in Askeladden. 190 meters southeast of detection 35 lies a registered Stone Age settlement at Oksholmen (ID 40142), but of course of no relevance for the detection (Figure 41).

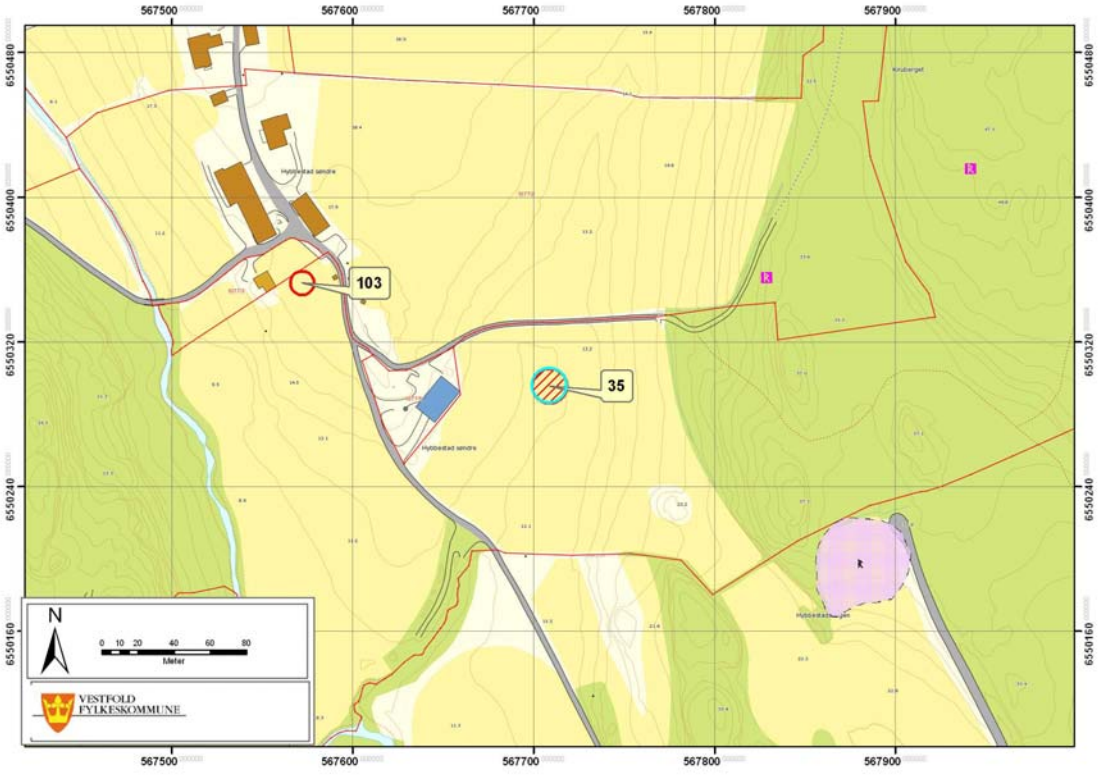


Figure 41. The location of detection No. 35.

4.1.4.3 Detection 294 site Vestre Virik. Gbnr 121/1 Sandefjord Municipality N 6553008.254 E 567624.878

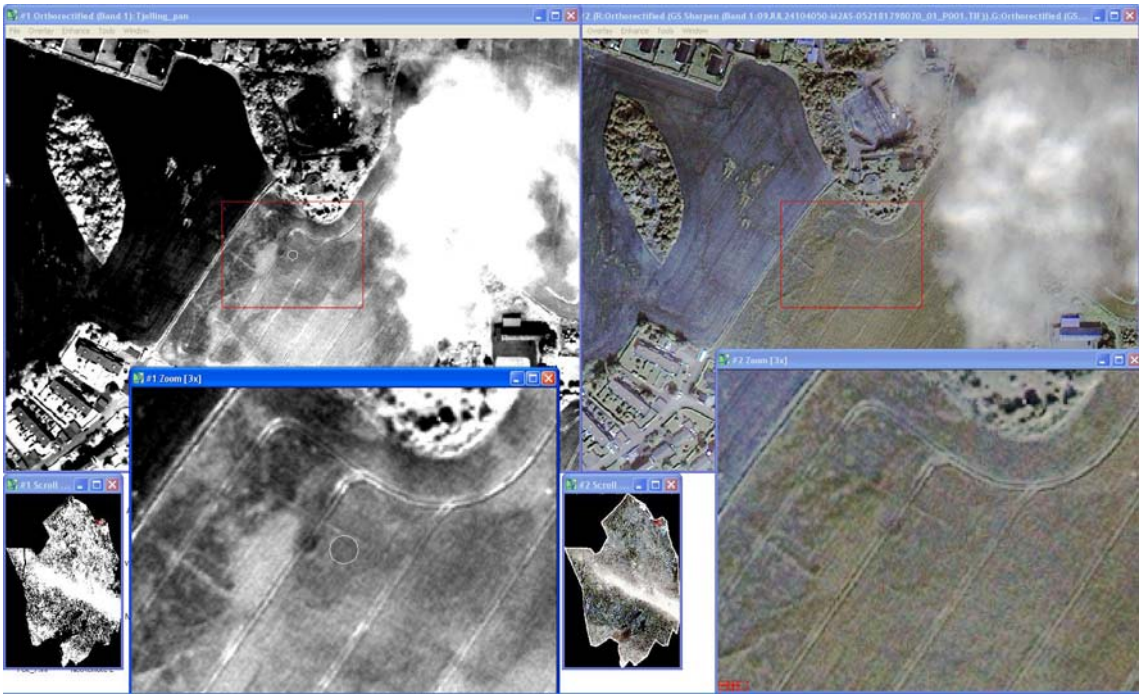


Figure 42. CultSearcher detection No. 294 in the Tjølling image.

This is a weak/uncertain detection (Figure 42). Further investigations in the field are necessary before including this detection in Askeladden. Detection 294 lies 50 meters south of removed grave cairn ID 39820, and 140 meters south of remains of grave cairn ID 49415 (Figure 43).

Figure 43. The location of detection No. 294. A removed grave cairn (dark grey) and the remains of a grave cairn (pink) are located 50 and 120 meters, respectively, north of the detection.

4.1.5 Examples of non-detected sites from the Tjølling image.

In the following text sites not detected by Cultsearcher, will be presented. These sites fall in two categories: (1) During manual inspection of detections made by CultSearcher, additional ring-shaped crop marks have been discovered close to Cultsearcher detections. (2) Previously known sites, which have either been discovered with aerial photography or by visual inspection in the field.

4.1.5.1 Site Lunde, near Tjøllingvolden in Larvik Municipality

This site (N 6 546 560, E 563 443.069) was first reported in October 2009. The local farmer had observed growth differences in the crop and reported this to the archaeologists in Vestfold County Council. During field inspections, one certain crop mark reflecting an over-ploughed grave mound was confirmed. When reviewing the Quickbird image of this site, one discernable crop mark is clearly visible (Figure 44). The nearby site (Askeladden ID 9298) lying just north of the newly discovered site, is registered as a grave field consisting of 4 grave mounds. The new site discovered at Lunde will be included in the existing site (Askeladden ID 9298).

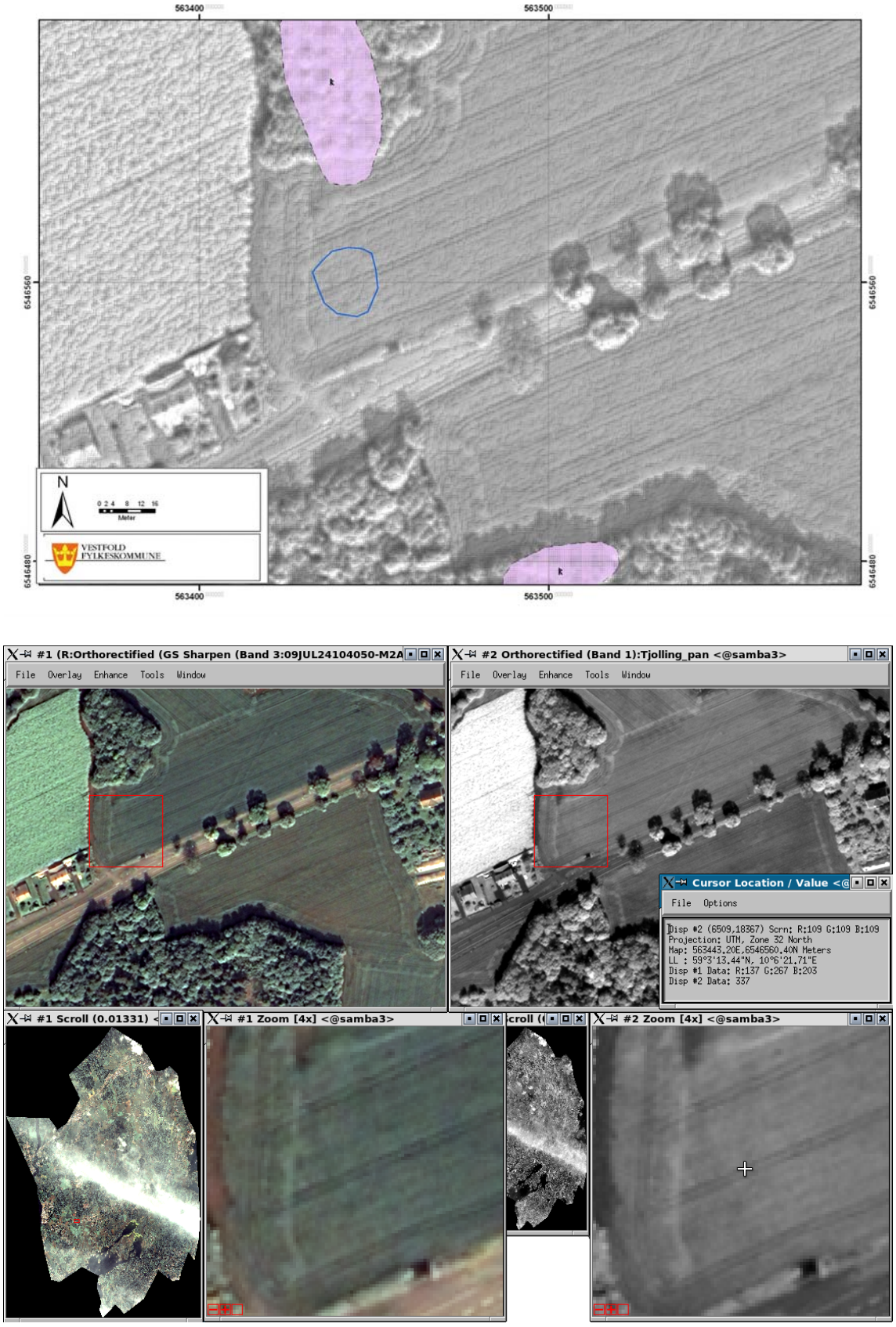


Figure 44. Crop mark at Lunde, inside the roughly sketched blue polygon. The crop mark was missed by CultSearcher. Pink areas denote known grave sites.

4.1.5.2 Site Skauen Gbnr 2027/3 Larvik Municipality

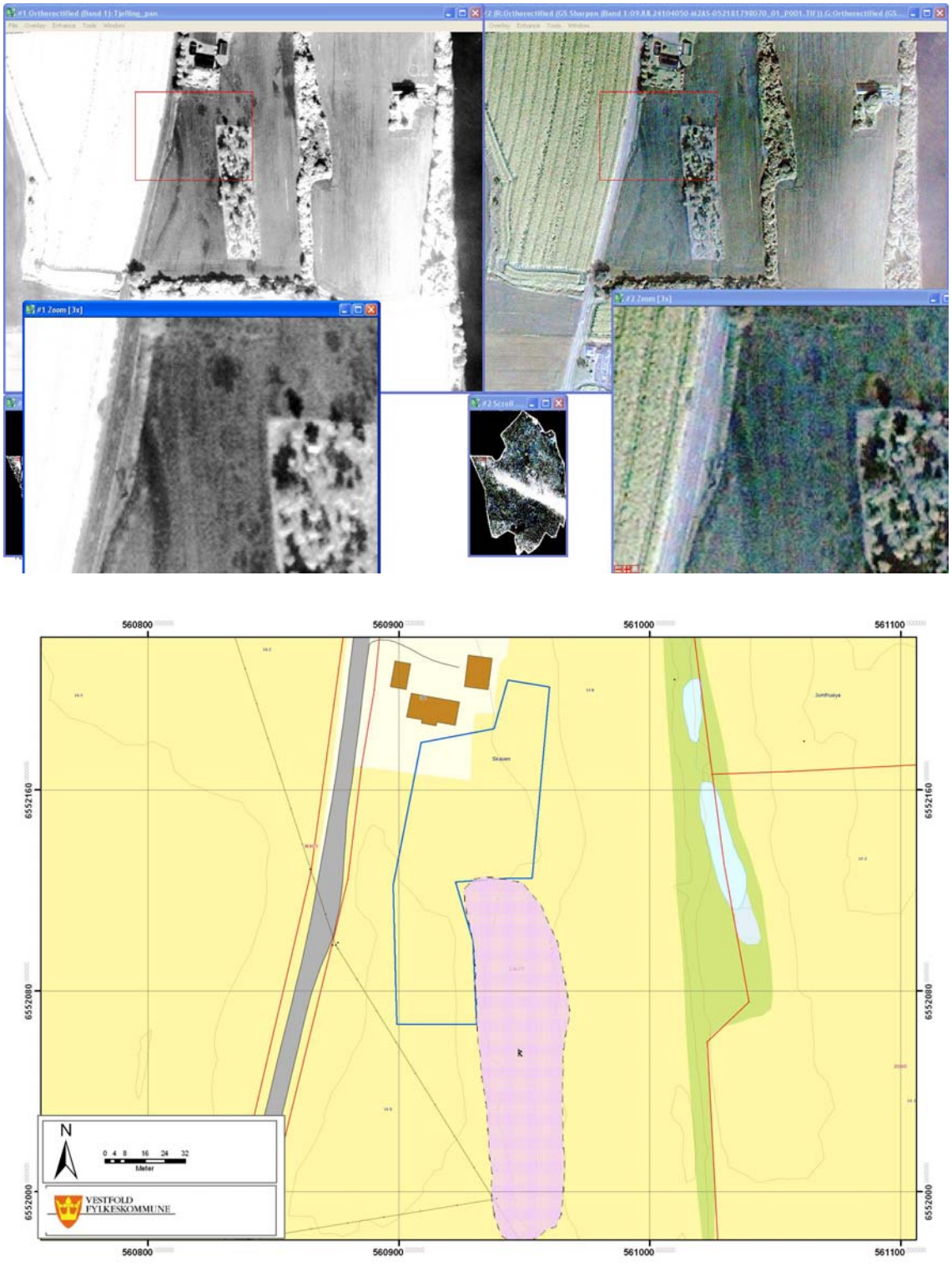


Figure 45. Top: crop marks at Skauen. These were not detected by CultSearcher. Bottom: the area containing the previously unknown cropmarks is outlined in blue. The pink area contains the previously known grave sites.

The circular features can be observed to the north and west of a known grave site (Figure 45) at Skauen (N 6552141.258 E 560920.932, Askeladden ID 135035). The present site covers a N-S

orientated 140m × 35m area, and consists of at least 23 circular mounds measuring 5-18m in diameter. At least 8 circular features can be observed in the satellite image, clearly representing plowed-out burial mounds which form an extension of the known site.

4.2 Experiences with Cultsearcher in Vestfold County Council 2009.

Ease of use is the one of the highlights using Cultsearcher in 2009. Previous experience with Cultsearcher in 2008 was a mixed experience. In 2008 we had to adjust the search parameters, like ring filter type and radius. This clearly made CultSearcher difficult to use. Even more importantly, in 2008 we had to clip out small search areas around known sites and apply the different search parameters. Performing full image searches, as done this year, would have been impossible for VCC with the 2008 version. The actual job of running CultSeacher on entire satellite scenes was performed by NR due to huge memory demands (in the order of 30 gigabytes), followed by VCC stepping through the detection results using CultSearcher. In VCC we view this sharing of work as imperative for future success for the Cultsearcher program in other counties in Norway.

The work done by NR to improve the search algorithm has also been a success. In 2008 CultSearcher did not detect any over-ploughed grave mounds unless the parameters for searching the image were set very wide. This could result in thousands of detections and the detection results were therefore quite useless.

In the Tjølling image, which VCC has concentrated on this year, we received 311 Cultsearcher detections from NR to validate., This is a manageable amount of detections to validate. But when validating detections we see that the agricultural masks, used for limiting the search area, still include a lot of trees and tree shadows. These are frequently marked as ring detections. This is especially evident in the transition zone from forest to arable land. This problem could probably be reduced by creating a negative bufferzone in the mask dataset.

The improvements made with Cultsearcher in 2009 both concerning user interface and success rate in detections is very promising. Sadly, the planned recording of further satellite data in 2009 was spoiled by the weather. Hopefully, new images may be acquired in 2010.

Archaeologists in Vestfold County are very pleased with the improvements of Cultsearcher done in 2009.

In the following illustrations we have visualized interpretations of detections with different filters and radius of the detections.

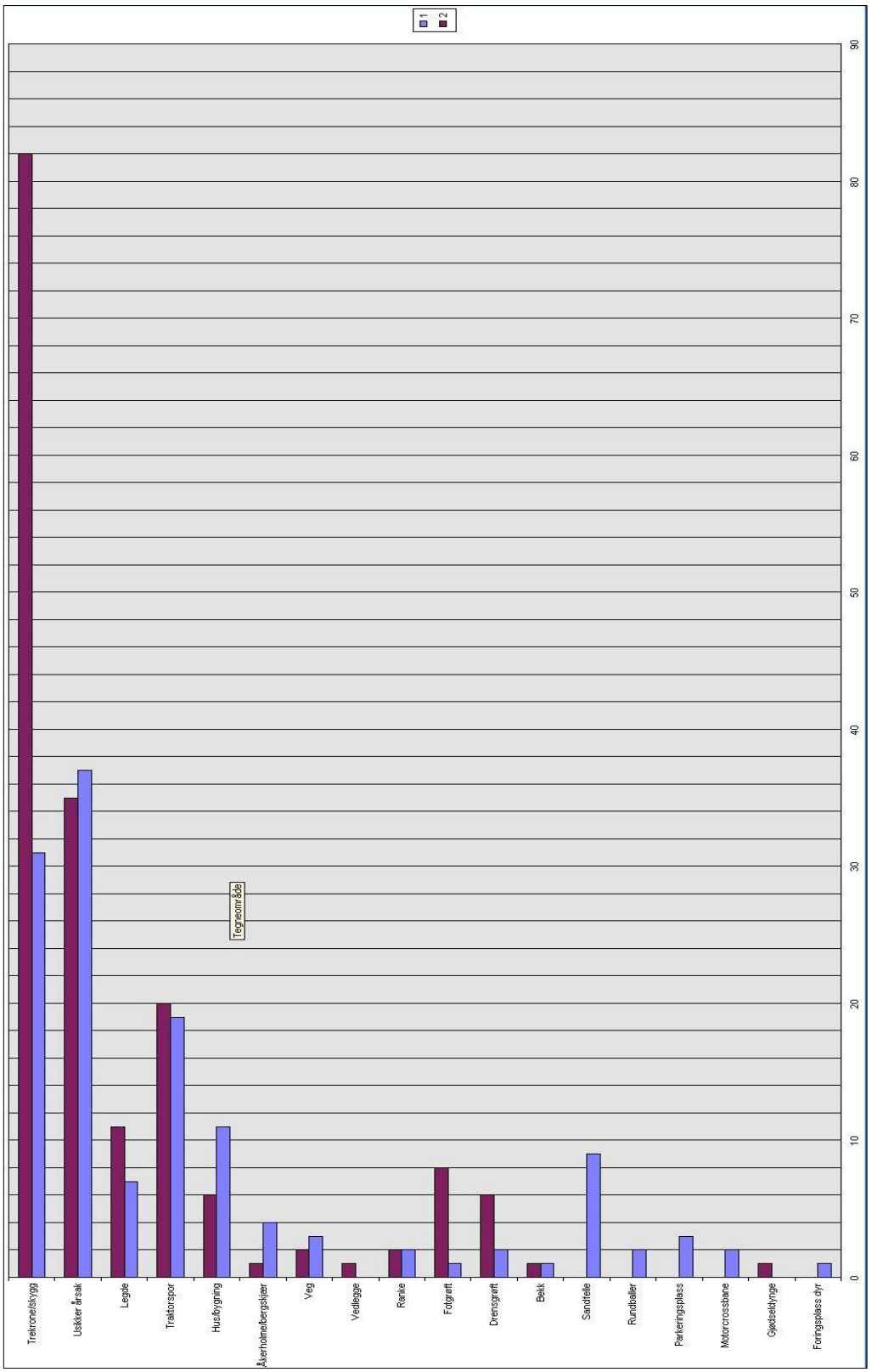


Figure 46. Histogram of ring detections. Purple denotes "type 1", that is, a ring edge separating a bright ring inside a dark area, and pale blue denotes "type 2", the opposite. The histogram groups, indicated along the horizontal axis, are in Norwegian, and denote various phenomena like tree crown or tree shadow (trekrone/skygge). “Fotgrøft” are the circular ditches that should be detected.

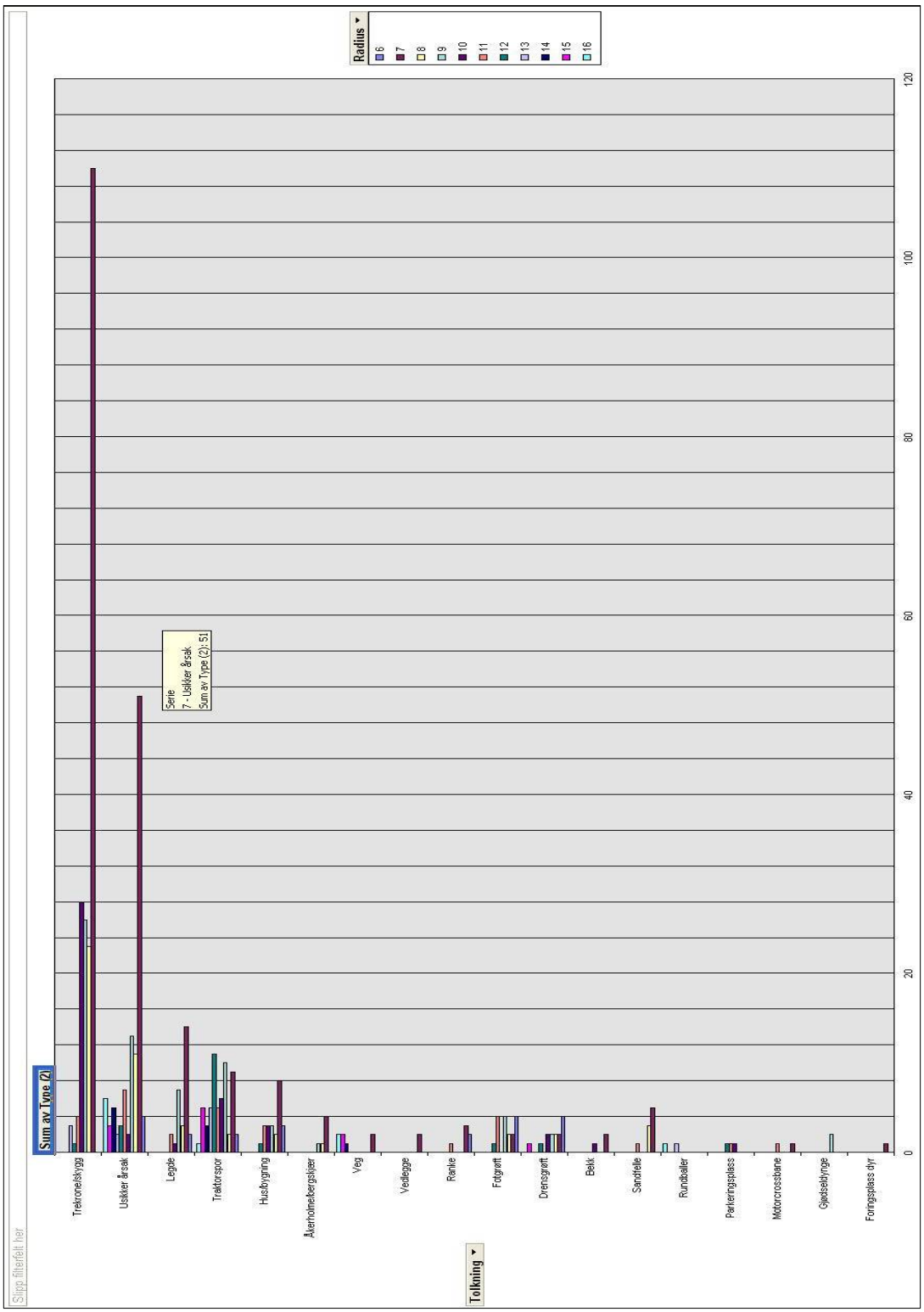


Figure 47. Histogram of ring radii for the various detections inFigure 46.

Table 3. All CultSearcher detections in the Tjølling image. Descriptions are in Norwegian.

ID_Deteksjon	Radius	Type	Beskrivelse	Tolkning
1	9	2	Valby Larvik, k. Et tidligere registrert gravfelt ID ????. Deler av feltet (sør) ligger intakt i skogholt. Nord for skogholtet fant P. Haavadsen vegetasjonsspor i form av fotgrøfter. Hans avgrensning av lokaliteten bør utvides mot nord ettersom deteksjon	Fotgrøft
2	12	1	Se notat under deteksjon 1, Lokalitet MÅ utvides mot nord.	Fotgrøft
3	6	2	Ligger på gbnr 125/4 Brønnum i Sandefjord kommune. Relativt svak , men korrekt detektert. Ikke registrert tidligere. Må legges inn i Askeladden. Mulig ytterligere en gravhaug rett sør for deteksjon 3, disse er forbundet med en bro (muligens).	Fotgrøft
4	12	1	Gbnr 1106/1. Ingen registrerte kulturminner fra før. Ligger midt i liten åkerlapp, relativt svak ring, men absolutt en ring og en positiv deteksjon	Fotgrøft
5	9	2	Falsk deteksjon, traktorspor vending. Gbnr 1029/4 ved Guri stasjon.	Traktorspor
6	6	1	Falsk deteksjon. Gbnr 1077/34 i Larvik kommune. På satelittfoto ser det ut for en bygning som reises, grunnmur ? Deteksjon 8 tilhører samme konstruksjon.	Hus/bygning
7	6	2	Falsk deteksjon, usikker på hva som har slått ut her ? Ser ut for å være ranker i en potetåker.	Ranke
8	6	1	Falsk deteksjon. Bygning. Gbnr	Hus/bygning
9	11	2	Svak deteksjon, men absolutt en positiv deteksjon. En enslig svale på gbnr 141/1 i Sandefjord kommune. Ikke registrert tidligere ASKELADDEN !	Fotgrøft
10	6	2	Falsk deteksjon, gbnr 125/7 i Sandefjord kommune	Usikker årsak
11	14	1	Falsk deteksjon, traktorspor, vending. På gbnr. 153/8 i Sandefjord kommune.	Traktorspor
12	11	1	Falsk deteksjon, ser ut for å være en sving på en motorcrossbane ? Som er plukket opp, deteksjon 283 er av samme type. På gbnr 150/12 Sandefjord kommune	Motorcrossbane
13	8	2	Falsk deteksjon, delvis dekket av skyer, usikker på hva som har slått ut ?. Ligger på gbnr 1070/3 i Larvik kommune	Usikker årsak
14	6	2	Falsk deteksjon, ligger mellom 4 drensgrøfter kan muligens forklare deteksjon. Ligger på gbnr 10224/1	Drensgrøft
15	9	2	Falsk deteksjon, traktorhjulspor. Ligger på gbnr 1029/5 i Larvik kommune.	Traktorspor

16	9	2	Falsk deteksjon traktorhjulspor, gbnr. 146/1 i Sandefjord kommune.	Traktorspor
17	9	1	Veldig svak ring, usikker som kulturminne. Bør sjekkes opp nærmere før ASKELADDEN	Usikker årsak
18	8	2	Falsk deteksjon, traktorspor på gbnr. 153/14 i Sandefjord kommune	Usikker årsak
19	10	1	Falsk deteksjon, usikker årsak (legde ?) Ligger på gbnr 148/8 i Sandefjord kommune. Men på motsatt (vest) side av driftsbygning 147/8 og NV for åkerholm er det et overpløyd gravfelt, ikke detektert av CS ASKELADDEN	Legde
20	11	2	Positiv deteksjon, tydelig ring i åker. Ikke registrert i Askeladden, ligger på gbnr. 1087/1, ved Klepåkerhelleren. Ligger nok ytterligere en haug umiddelbart øst for 20 (nr 236), samt en ring sørafor som ikke er deterktert av CS (kan være korn som har	Fotgrøft
21	13	1	Falsk deteksjon, traktorspor på gbnr 146/1 Furustad nordre i Sandefjord kommune.	Traktorspor
22	7	2	Falsk deteksjon, traktorspor. På gbnr 127/1 Sørby i Sandefjord k.	Traktorspor
23	7	2	Falsk deteksjon, hage ? Gbnr 2036/1 Larvik kommune	Hus/bygning
24	8	2	Falsk deteksjon, usikkert hva som har slått ut. Gbnr 144/4 i Sandefjord kommune	Usikker årsak
25	11	1	Falsk deteksjon traktorspor/snu på gbnr 127/1 Sørby i Sandefjord kommune.	Traktorspor
26	8	2	Falsk deteksjon. Omfattende drensgrøfting. Ligger sørvest for ring 1 og 51, gbnr 1027/2	Drensgrøft
27	9	2	Falsk deteksjon. Traktorspor/snu. På gbnr 1031/1 i Larvik kommune.	Traktorspor
28	7	2	Falsk deteksjon. Traktorspor/snu. På gbnr 155/4 i Sandefjord kommune.	Traktorspor
29	11	2	Falsk deteksjon. Korn som har lagt seg. På gbnr. 1010/1 i Larvik kommune.	Legde
30	11	1	Falsk deteksjon. Ser ut som enten ranke i åker evt annet ? På gbnr 1082/3 i Larvik kommune.	Ranke
31	14	1	Falsk deteksjon traktorspor/snu. På gbnr. 1031/1 i Larvik kommune.	Traktorspor
32	12	1	Falsk deteksjon. Traktorspor/snu. På gbnr. 154/1 i Sandefjord kommune.	Traktorspor
33	13	2	Falsk deteksjon. Kjørespor i åker. På gbnr 128/1 i Sandefjord kommune.	Traktorspor
34	11	1	Falsk deteksjon. Traktorspor/snu. På gbnr 1031/1 i Larvik kommune.	Traktorspor
35	16	1	Positiv detekson. Svakt utslag, usikker på gehalt.. På gbnr. 1077/1 i Larvik kommune.	Usikker årsak

36	12	2	Falsk deteksjon. Usikkert utslag. På gbnr. 130/4 i Sandefjord kommune.	Usikker årsak
37	6	2	Falsk deteksjon. Usikkert utslag, åkerholme ? På gbnr. 134/3 i Sandefjord kommune.	Usikker årsak
38	8	2	Falsk ringdeteksjon. MEN kan se ut for at CS har funnet gammelt tun ? Evt geilsystem eller lignende Ligger ved gamle Raveg rett NØ for Rødbøl. ASKELADDEN ?	Usikker årsak
39	12	1	Falsk ringdeteksjon. Traktorspor/snu. Ligger på gbnr. 147/2 i Sandefjord.	Traktorspor
40	10	1	Falsk deteksjon. Krok i bekk. Ligger på gbnr 132/27 i Sandefjord kommune.	Bekk
41	12	1	Falsk deteksjon. Traktorspor/snu. Ligger på gbnr. 1032/21 i Larvik kommune, rett NNV for Husebyhaugen.	Traktorspor
42	6	2	Falsk deteksjon. Traktorspor/snu, ligger på gbnr 1031/20 i Larvik kommune.	Traktorspor
43	10	2	Falsk deteksjon. Traktorspor/snu. Ligger på gbnr 149/6 i Sandefjord kommune.	Traktorspor
44	15	2	Falsk deteksjon. Usikkert utslag. Ligger på gbnr. 1047/1	Usikker årsak
45	7	2	Falsk deteksjon. Usikkert utslag. Ligger på gbnr. 1066/1 i Larvik kommune.	Usikker årsak
46	14	2	Falsk deteksjon. Usikkert utslag. Ligger på gbnr. 141/5 i Sandefjord kommune	Usikker årsak
47	9	2	Falsk deteksjon, MEN rett VNV for 47 ligger en svak ring CS ikke plukker opp. ASKELADDEN ? Ligger på gbnr 129/64 i Sandefjord	Drensgrøft
48	10	2	Falsk deteksjon traktorspor/snu. Ligger på gbnr. 1023/21 i Larvik kommune, rett ved Huseby.	Traktorspor
49	6	2	Falsk deteksjon, drensgrøfter. Pågbnr 1077/1 i Larvik kommune	Drensgrøft
50	16	1	Falsk deteksjon, usikker årsak. På gbnr 1066/2 Lund i Larvik kommune.	Usikker årsak
51	10	2	Falsk deteksjon ? Drensgrøfter. Ligger ret sør for deteksjon 1 og 2, men innenfor lokalitetsavgrensning. På gbnr 1027/2 i Larvik.	Drensgrøft
52	12	2	Falsk deteksjon. Traktorspor/snu. På gbnr. 130/4 Hystad Østre i Sandefjord kommune.	Traktorspor
53	7	2	Falsk deteksjon. Drensgrøfter. På gbnr. 1024/1 i Larvik kommune.	Drensgrøft
54	9	2	Falsk deteksjon, traktorspor. På gbnr. 2041/9 i Larvik kommune.	Traktorspor
55	14	1	Falsk deteksjon. Veier på tun. På gbnr. 155/1,4,8 i Sandefjord kommune.	Veg
56	12	1	Falsk deteksjson. Traktorspor/snu. På gbnr. 1056/2.	Traktorspor

57	12	2	Falsk deteksjon. Traktorspor/snu. På gbnr 145/1	Traktorspor
58	8	2	Falsk deteksjon. Traktorspor/snu. På gbnr. 1031/20	Traktorspor
59	11	2	Falsk deteksjon. Traktorspor/snu. På gbnr. 121/1 i Sandefjord kommune.	Traktorspor
60	10	2	Falsk deteksjon. Traktorspor/snu. På gbnr.153/8 i Sandefjord kommune.	Traktorspor
61	14	1	Falsk deteksjon. Traktorspor/snu. På gbnr. 1031/20 i Larvik kommune.	Traktorspor
62	12	1	Falsk ringdeteksjon MEN ligger en merkelig cluster av grøfter ved deteksjon,. Disse strekker seg ut i vifteform ASKELADDEN ?. Ligger på gbnr 1067/2	Drensgrøft
63	10	2	Falsk deteksjon. Usikker årsak. På gbnr. 1041/9	Usikker årsak
64	13	1	Falsk deteksjon?. Traktorspor. På gbnr 2028/1 i Larvik kommune. Deteksjonen ligger svært tett på gravfeltet ID 91148 som ligger i vest, og det kan være en reell deteksjon.	Traktorspor
65	9	2	Falsk deteksjon. Usikker årsak. På gbnr. 125/5	Usikker årsak
66	11	2	Falsk deteksjon. Usikker årsak. På gbnr. 1036/9 i Larvik kommune.	Usikker årsak
67	16	2	Falsk deteksjon. Usikker årsak. På gbnr. 1082/1 i Larvik kommune.	Usikker årsak
68	11	1	Falsk ringdeteksjon. Traktorspor/snu. På gbnr. 1056/2 i Larvik kommune. MEN øst for detksjon og midt i åker ligger en ring med indre kammer ? ASKELADDEN..veldig usikker.	Traktorspor
69	12	1	Falsk deteksjon. Traktorspor/snu. På gbnr. 1025/1	Traktorspor
70	11	2	Falsk deteksjon. Usikker årsak. På gbnr. 1064/6 i Larvik kommune.	Usikker årsak
71	11	2	Falsk deteksjon. Usikker årsak. På gbnr. 146/2	Usikker årsak
72	16	1	Falsk deteksjon. Traktorspor/snu. På gbnr. 121/1. Sandefjord kommune.	Traktorspor
73	7	2	Falsk deteksjon. Usikker årsak/tørr flekk i åker. På gbnr. 1041/9.	Usikker årsak
74	14	2	Falsk deteksjon. Usikker årsak. På gbnr. 132/6,23	Usikker årsak
75	12	1	Falsk deteksjon. Traktorspor/snu. På gbnr. 127/1	Traktorspor
76	9	1	Falsk deteksjon. Usikker årsak. På gbnr. 133/2 Sandefjord	Usikker årsak
77	13	1	Falsk deteksjon. Traktorspor/snu. På gbnr. 1032/21 Huseby.	Traktorspor
78	12	1	Falsk deteksjon. Usikker årsak. På gbnr. 1032/30.	Usikker årsak
79	10	2	Falsk deteksjon. Trær ? På gbnr. 133/2 i Sandefjord kommune.	Trekrone/skygg

80	14	1	Falsk deteksjon. Usikker årsak. 1036/9 Larvik kommune	Usikker årsak
81	15	2	Falsk deteksjon. Traktorspor. På gbnr. 2028/1 i Larvik.	Traktorspor
82	12	1	Falsk deteksjon. Traktorspor/snu. På gbnr 153/9 Sandefjord kommune.	Traktorspor
83	15	1	Falsk deteksjon. Drensgrøfter, ligger sør for deteksjon 1 og 2., dvs rett vest for lokalitet.	Drensgrøft
84	15	1	Falsk deteksjon. Usikker årsak. På gbnr. 1038/1	Usikker årsak
85	6	2	Falsk deteksjon. Hus. Gbnr. 128/24 Sandefjord.	Hus/bygning
86	11	1	Falsk deteksjon. Usikker årsak. Gbnr. 1069/1	Usikker årsak
87	15	1	Falsk deteksjon. Vei. Gbnr 155/1,4,8	Veg
88	10	2	Falsk deteksjon. Husklynge Gbnr.1038/6	Hus/bygning
89	16	2	Falsk deteksjon. Usikker årsak. Gbnr 1027/1	Usikker årsak
90	12	1	Falsk deteksjon. Hjulspor/grøft. Gbnr. 146/2. Sandefjord.	Hus/bygning
91	6	2	Falsk deteksjon, korn som har lagt seg. Gbnr.147/39	Legde
92	15	1	Falsk deteksjon, Hjulspor. Gbnr 121/1 Sandefjord	Traktorspor
93	15	1	Falsk deteksjon. VEG/TUN, gbnr. 150/7 m.fl.	Veg
94	13	2	Falsk deteksjon. Usikker årsak. Gbnr 129/109	Usikker årsak
95	13	1	Falsk deteksjon. SKOGHOLT. Gbnr. 2037/7 Larvik kommune.	Trekrone/skygg
96	10	1	Falsk deteksjon. Biler på parkeringsplass. Gbnr. 132/424	Parkeringsplass
97	9	2	Falsk deteksjon. Usikker årsak. Gbnr. 147/8	Usikker årsak
98	9	1	Falsk deteksjon. Usikker årsak. Gbnr. 147/39	Usikker årsak
99	10	1	Falsk deteksjon, hus ? Gbnr. 137/14	Hus/bygning
100	11	2	Falsk deteksjon. Hus/parkering. Gbnr. 152/1	Hus/bygning
101	12	1	Falsk deteksjon. Parkeringsplass. Gbnr.152/97, Sandefjord kommune.	Parkeringsplass
102	16	1	Falsk deteksjon. Rekke med rundballer som ligger i vinkel. Gbnr.1099/3, Larvik kommune.	Rundballer
103	11	1	Falsk deteksjon. Inne på tun, bil +++ Gbnr 1077/1	Parkeringsplass
104	13	1	Falsk deteksjon. Rekke med rundballer. Gbnr.1018/1	Rundballer
105	16	2	Falsk deteksjon. Rundkjøring på E18. HVORFOR er kun den ene rundkjøringen detektert ? Nordvest for 105 er en identisk rundkjøring, den er ikke detektert ???	Veg

106	7	2	Mulig deteksjon. Korn som har lagt seg i en sirkulær flate ? I Norge i bilder sees mørke flekker (soilmarks?) her. Usikker. Gbnr.1076/2 Larvik kommune.	Legde
107	9	2	Falsk deteksjon, tuntre Gbnr. 1064/2 Larvik. Ligger innenfor lokalitet ID 78347 bosetningsområde. Ingen deteksjoner som sees i QB. Har eksportert fra norge i bilder to bilder som kanskje kaster mer lys over lokaliteten.	Trekrone/skygg
108	7	2	Falsk deteksjon, tre i kant av jorde. Gbnr. 2042/9,30 Larvik kommune.	Trekrone/skygg
109	7	2	Falsk deteksjon, tre i kant av jorde. Gbnr 1105/6, Larvik kommune.	Trekrone/skygg
110	7	2	Falsk deteksjon, treklynge i kant av jorde. Gbnr. 128/24 Sandefjord kommune	Trekrone/skygg
111	7	2	Falsk deteksjon. Treklynge i kant av jorde. Gbnr. 1097/2 Larvik kommune.	Trekrone/skygg
112	7	1	Falsk deteksjon. Sandfelle på golfbane. Gbnr 137/6 Sandefjord.	Sandfelle
113	8	2	Falsk deteksjon. Skygge fra tre. Gbnr 1028/16	Trekrone/skygg
114	7	2	Falsk deteksjon treskygge. Gbnr 1093/5. Larvik kommune.	Trekrone/skygg
115	7	2	Falsk deteksjon, treskygge. Gbnr. 1097/2 Larvik	Trekrone/skygg
116	7	2	Falsk deteksjon. Treskygge. Gbnr. 125/1 Sandefjord	Trekrone/skygg
117	8	2	Falsk deteksjon. Treskygge. Gbnr. 146/2. Sandefjord.	Trekrone/skygg
118	7	2	Falsk deteksjon. Treskygge. Gbnr. 150/23. Sandefjord	Trekrone/skygg
119	9	1	Falsk deteksjon, korn som har lagt seg. Gbnr. 145/2,3	Legde
120	7	2	Falsk deteksjon, treskygge. Gbnr 150/31 Sandefjord	Trekrone/skygg
121	9	2	Falsk deteksjon. Treskygge. Gbnr. 1071/1 Larvik	Trekrone/skygg
122	7	2	Falsk deteksjon. Vedlegge ? Gbnr. 1091/1, Larvik kommune.	Vedlegge
123	7	2	Falsk deteksjon. Treskygge. Gbnr 1111/3 Larvik k	Trekrone/skygg
124	9	2	Falsk deteksjon, treskygge. Gbnr. 149/3 Sandefj k	Trekrone/skygg
125	9	2	Falsk deteksjon. Treskygge. Gbnr. 1106/2 Larvik kommune.	Trekrone/skygg
126	7	1	Falsk deteksjon. Treskygge effekt. Gbnr.1010/1 Larvik k	Trekrone/skygg
127	7	2	Feildeteksjon. Korn som har lagt seg. Gbnr. 2049/2 Larvik.	Legde
128	7	1	Falsk deteksjon. Sandfelle golfbane. Gbnr.139/5	Sandfelle
129	7	2	Falsk deteksjon, korn som har lagt seg. Gbnr 1036/20 Larvik.	Legde

130	7	1	Falsk deteksjon. Sandfelle golfbane. Gbnr 139/5	Sandfelle
131	7	2	Falsk deteksjon. Garasje (firkantet !!!) Gbnr. 130/227 Sandefjord k	Hus/bygning
132	7	2	Falsk deteksjon, treskygge. Gbnr.2042/5 Larvik	Trekrone/skygg
133	7	2	Falsk deteksjon. Usikker årsak. Kantete vegetasjonsmerke, ikke en sluttet ring, ?? Gbnr 155/22	Usikker årsak
134	7	2	Falsk deteksjon treskygge, gbnr 153/15 Sandefjord k	Trekrone/skygg
135	7	2	Falsk deteksjon, treskygge. Gbnr 131/1 Sandefjord	Trekrone/skygg
136	9	2	Falsk deteksjon. Treskygge. Gbnr 147/11 Sandefjord	Trekrone/skygg
137	7	2	Falsk deteksjon Treskygge, gbnr 1090/11 Larvik	Trekrone/skygg
138	7	2	Falsk deteksjon, treskygge, gbnr 1058/1 Larvk	Trekrone/skygg
139	7	1	Falsk deteksjon. Sandfelle golfbane, gbnr 137/13m, Sandefjord k	Sandfelle
140	7	2	Falsk deteksjon Treskygge, gbnr 134/8, Sandefjord.	Trekrone/skygg
141	8	1	Falsk deteksjon, treskygge, gbnr. 1035/7, Larvik.	Trekrone/skygg
142	10	2	Falsk deteksjon, treskygge, gbnr 149/6	Trekrone/skygg
143	8	2	Falsk deteksjon, treskygge, gbnr 1036/64	Trekrone/skygg
144	7	1	Falsk deteksjon, trekrone. Gbnr. 1078/2	Trekrone/skygg
145	9	2	Falsk deteksjon, gjødseldynge, gbnr 150/31, Sandefjord	Gjødseldynge
146	7	2	Falsk deteksjon trekrone/skygge. Gbnr 1081/2. Larvik	Trekrone/skygg
147	10	2	Falsk deteksjon, treskygge. Gbnr. 1026/3. Larvik.	Trekrone/skygg
148	7	2	Falsk deteksjon, treskygge. Gbnr. 128/24	Trekrone/skygg
149	7	2	Falsk deteksjon. Veifylling. Gbnr 2041/2 Larvik.	Veg
150	7	2	Falsk deteksjon, treskygge, gbnr. 106/1. Sandefjord kommune.	Trekrone/skygg
151	7	2	Falsk deteksjon. Trekrone. Gbnr. 1035/2. Larvik kommune.	Trekrone/skygg
152	7	1	Falsk deteksjon usikker årsak, muligens traktorspor fra harving (se illustrasjoner), gbnr 128/24 Sandefjord	Usikker årsak
153	7	2	Falsk deteksjon. Bergskjær ? Gbnr. 1064/5, Larvik.	Åkerholme/bergskjær
154	10	2	Falsk deteksjon, trekrone/skygge. Gbnr.1018/3, Larvik.	Trekrone/skygg
155	7	2	Falsk deteksjon. Usikker årsak, veibygging ? Gbnr 2045/1 Larvik.	Trekrone/skygg
156	10	2	Falsk deteksjon. Trekrone/Skygge, gbnr 133/11 Sandefjord	Trekrone/skygg

157	7	2	Falsk deteksjon, trekrone/skygge, gbnr. 125/4 Sandefjord	Trekrone/skygg
158	7	2	Falsk deteksjon. Trekrone/skygge, gbnr. 1095/2, Larvik	Trekrone/skygg
159	7	2	Falsk deteksjon. Trekrone/skygge gbnr. 1031/1, Larvik	Trekrone/skygg
160	7	2	Falsk deteksjon, usikker årsak, mulig deteksjon. Soilmark ?? Gbnr 1031 Larvik	Usikker årsak
161	9	1	Falsk deteksjon ?? Usikker, mulig soilmark, men kan også være foringsplass for kyr. Ser ut for at det er kyr på nærmeste gård. Gbnr 1077 Larvik.	Usikker årsak
162	7	1	Falsk deteksjon, trekrone/skygge. Gbnr.1107/1	Trekrone/skygg
163	9	2	Falsk deteksjon. Trekrone/skygg gbnr. 149/2 Sandefjord.	Trekrone/skygg
164	7	2	Sikker deteksjon på nordre Kaupang, haugen har nok inngått i det store gravfeltet Nicolaysen har tegnet opp. Haugen er muligens også nevnt i Kaupang publ bind 1. Gbnr. 1029/3	Fotgrøft
165	9	1	Falsk deteksjon. Legde. Gbnr. 145/2,3 Sandefjord	Legde
166	8	1	Falsk deteksjon. Legde.Gbnr 139/1. Sandefjord	Legde
167	7	2	Falsk deteksjon. Trekrone/skygge gbnr.1010/2	Trekrone/skygg
168	7	1	Falsk deteksjon. Foringsplasser til kyr ? Gbnr.146/21 Sandefjord.	Foringsplass dyr
169	7	2	Falsk deteksjon. Trekrone/skygge. Gbnr.159/9, Sandefjord	Trekrone/skygg
170	13	2	Falsk deteksjon. Trekrone/skygge. Gbnr 156/1 Sandefjord.	Trekrone/skygg
171	7	1	Falsk deteksjon. Trekrone/skygge. Gbnr 1033/1. Larvik.	Trekrone/skygg
172	9	2	Falsk deteksjon. Trekrone/skygge. Gbnr. 1087/3	Trekrone/skygg
173	10	2	Falsk deteksjon. Trekrone/skygge. Gbnr. 153/7, Sandejford kommune.	Trekrone/skygg
174	8	2	Falsk deteksjon. Trekrone/skygge. Gbnr 112/4 Sandefjord.	Trekrone/skygg
175	7	1	Falsk deteksjon. Usikker årsak. Gbnr. 1086/1. Larvik	Usikker årsak
176	7	2	Falsk deteksjon. Trekrone/skygge. Gbnr 1045/4	Trekrone/skygg
177	8	2	Falsk deteksjon. Trekrone/skygge. Gbnr 1033/1, Larvik. MEN vest for 177 ligger en udetektert fotgrøft som er bekreftet i felt oktober 2009. Forlengelse av gravfeltet ID 9298	Trekrone/skygg
178	7	1	Falsk deteksjon. Usikker årsak. Gbnr. 1044/10. Larvik (Tjølling travebane).	Usikker årsak
179	7	1	Falsk deteksjon. Trekrone/skygge. Gbnr.121/140. Sandefjord	Trekrone/skygg

180	7	2	Falsk deteksjon. Trekrone/skygge. Gbnr 1069/2 Larvik.	Trekrone/skygg
181	7	1	Falsk deteksjon. Hus. Gbnr. 130/219	Hus/bygning
182	7	1	Falsk deteksjon. Legde. Gbnr.1114/1, Larvik	Legde
183	10	2	Falsk deteksjon.Trekrone/skygge, gbnr 132/82 Sandejford	Trekrone/skygg
184	7	2	Falsk deteksjon. Usikker årsak. Gbnr 1008/3. Larvik	Usikker årsak
185	9	1	Falsk deteksjon. Legde. Gbnr.144/12 Sandejford.	Legde
186	9	2	Falsk deteksjon, trekrone/ skygge. Gbnr 1020/1 Larvik. Forneminnetett område på Rauan/Kjerneberget	Trekrone/skygg
187	11	2	Falsk deteksjon. Trekrone/skygge gbnr. 1070/1 Larvik	Trekrone/skygg
188	10	2	Falsk deteksjon. Trekrone/skygge. Gbnr 2030/2, Larvik.	Trekrone/skygg
189	7	1	Falsk deteksjon. Usikker årsak. Gbnr 2040/2 Larvik.	Usikker årsak
190	7	1	Falsk deteksjon. Usikker årsak. Gbnr. 1099/3 Larvik	Usikker årsak
191	10	2	Falsk deteksjon. Trekrone/skygge. Gbnr. 1018/1, Larvik	Trekrone/skygg
192	7	2	Falsk deteksjon, Trekrone/skygge. Gbnr. 2034/10 Larvik	Trekrone/skygg
193	8	2	Falsk deteksjon. Trekrone/skygge. Gbnr. 147/8. Sandefjord	Trekrone/skygg
194	7	1	Falsk deteksjon. Usikker årsak. Gbnr. 1064/12	Usikker årsak
195	7	2	Falsk deteksjon trekrone/skygge, gbnr. 2045/2	Trekrone/skygg
196	7	1	Falsk deteksjon. Usikker årsak. Gbnr. 1092/2 Larvik	Usikker årsak
197	8	1	Falsk deteksjon, midt i drivvhus !! Gbnr. 1008/1 Larvik	Hus/bygning
198	8	1	Falsk deteksjon. Trekrone/skygge. Gbnr 1033/1 Larvik.	Trekrone/skygg
199	7	1	Falsk deteksjon. Trekrone/skygge. Gbnr. 127/9	Trekrone/skygg
200	7	1	Falsk deteksjon, usikker årsak. Gbnr. 1015/2 Larvik.	Usikker årsak
201	7	1	Falsk deteksjon. Trekrone/skygge. Gbnr 1068/3 Larvik.	Trekrone/skygg
202	7	1	Falsk deteksjon. Trekrone/skygge, gbnr 1010/7 Larvik.	Trekrone/skygg
203	7	2	Falsk deteksjon.Usikker årsak. Gbnr 2042/160	Usikker årsak
204	7	2	Falsk deteksjon. Trekrone skygge. Gbnr. 128/541, Sandefjord	Trekrone/skygg
205	7	2	Falsk deteksjon. Hull i skylag. Gbnr 1022/2 Larvik.	Usikker årsak
206	8	2	Falsk deteksjon. Trekrone/skygge. Gbnr.1091/1 Larvik.	Trekrone/skygg
207	7	1	Falsk deteksjon. Trekrone/skygge. Gbnr 133/2 Sandefjord.	Trekrone/skygg

208	9	1	Falsk deteksjon. Åkerholme. Gbnr 1043/2 Larvik	Åkerholme/bergskjær
209	7	1	Falsk deteksjon. Sandfell golfbane. Gbnr 137/6 Sandefjord.	Sandfelle
210	10	2	FD Trekrone/skygge. Gbnr. 1028/1 Larvik	Trekrone/skygg
211	7	2	FD Trekrone/skygge. Gbnr. 146/1, Sandefjord.	Trekrone/skygg
212	7	1	FD. Trekrone/skygge. Gbnr 2028/1 Larvik.	Trekrone/skygg
213	7	2	FD Ranke i åker. Gbnr. 1093/1, Larvik.	Ranke
214	7	1	FD Treskygge/krone gbnr. 1096/1	Trekrone/skygg
215	11	2	FD Trekrone/Skygge gbnr 159/9, Sandefjord.	Trekrone/skygg
216	7	2	FD Treskygge/krone Gbnr.134/2	Trekrone/skygg
217	8	1	FD Tak Gbnr.155/4 Sandefjord	Hus/bygning
218	9	2	FD Tak. Gbnr 129/235 Sandefjord	Hus/bygning
219	9	1	FD Usikker årsak, gbnr 128/24, Sandefjord	Usikker årsak
220	8	2	FD Treskygge/krone, gbnr 1064/2. Larvik. Ligger innenfor lok avgrensning til Id 78347. Bosetning og aktivitetsområde. Intet observerbart på åkerflate.	Trekrone/skygg
221	7	1	FD Trekrone/skygge. Gbnr 132/37 Sandefjord	Trekrone/skygg
222	7	1	FD Treskygge/krone, gbnr.1091/1 Larvik	Trekrone/skygg
223	9	2	FD Legde. Gbnr. 132/82. Sandefjord.	Legde
224	8	1	FD Trekrone/skog. Gbnr 125/5. Ligger innenfor uavklart lokalitet "Funnsted Kølabonn" ID 78001 Sandefjord	Trekrone/skygg
225	9	1	FD Trekrone/skygge Gbnr. 2042/6 Larvik	Trekrone/skygg
226	7	2	FD Usikker årsak. Gbnr 1043/2,3,9 Larvik	Usikker årsak
227	9	2	FD Trekrone/skygge gbnr 155/14 Sandefjord.	Trekrone/skygg
228	7	1	FD Trekrone/skygge gbnr. 1087/1 Larvik.	Trekrone/skygg
229	7	1	FD. Tak (firkantet) gbnr.150/1 Sandefjord.	Hus/bygning
230	7	2	FD Trekrone/skygge gbnr 2041/9, Larvik.	Trekrone/skygg
231	7	2	FD Legde. Gbnr 1022/2 Larvik	Legde
232	7	2	FD Bekkeleie. Gbnr. 135/3,6 Sandefjord.	Bekk
233	7	1	FD Usikker årsak. Gbnr 2039/2 Larvik	Usikker årsak
234	7	2	FD. Trekrone/skygge. Gbnr 1078/2 Larvik	Trekrone/skygg
235	10	2	FD. Treskygge/krone. Gbnr 2042/ 9,30	Trekrone/skygg
236	8	2	Positiv deteksjon. Se deteksjon 20 (hører sammen). Gbnr 1087/1 Larvik.	Fotgrøft
237	7	1	FD. Usikker årsak, legde? Gbnr 1012/2 Larvik.	Usikker årsak

238	7	1	FD Trekrone/skygge Gbnr. 149/27. Sandefjord.	Trekrone/skygg
239	7	2	FD Legde. Gbnr 1052/1 Larvik	Legde
240	7	1	FD Legde gbnr.2035/4, Larvik.	Legde
241	10	2	FD Treskygge/krone gbnr 1114/4. Larvik.	Trekrone/skygg
242	7	1	FD treskygge/krone Gbnr 1114/1	Trekrone/skygg
243	7	1	FD Treskygge/krone Gbnr 128/10. Sandefjord.	Trekrone/skygg
244	7	2	FD Treskygge/krone gbnr. 1091/1 Larvik	Trekrone/skygg
245	10	2	FD Trekrone/skygge gbnr 1021/2. Larvik	Trekrone/skygg
246	7	1	FD Veldig usikker, kan være en svak korrekt deteksjon. Gbnr 1039/1 Larvik	Usikker årsak
247	7	1	FD Hus gbnr 1022/2 Larvik	Usikker årsak
248	7	1	FD Usikker deteksjon. Rett ved toglinje 1074/2 Larvik	Hus/bygning
249	8	2	FD Treskygge/krone gbnr 1112/1 Larvik	Trekrone/skygg
250	7	2	FD Usikker årsak. Gbnr 2034/10 Larvik.	Usikker årsak
251	7	1	Usikker deteksjon/mulig svak ring. Ligger nær golfbane, mest sannsynlig ikke. Gbnr 147/4 Sandefjord	Usikker årsak
252	7	1	FD Trekrone/skygge. Gbnr 149/12 Sandefjord	Trekrone/skygg
253	7	1	FD Trekrone/skygge. Gbnr 1009/1, Larvik	Trekrone/skygg
254	8	1	Bergskjær/legde. Gbnr 141/5 Sandefjord	Åkerholme/bergskjær
255	8	1	FD Usikker årsak. Gbnr 141/5, Sandefjord	Usikker årsak
256	7	1	FD. Usikker årsak/svak ring. Gbnr 1054/4 Larvik	Usikker årsak
257	7	2	FD. Trekrone/skygge. Gbnr 1092/1 Larvik	Trekrone/skygg
258	7	2	FD. Trekrone/skygge. Gbnr 127/5. Sandefjord.	Trekrone/skygg
259	7	2	FD. Trekrone/skygge. Gbnr 1070/1 Larvik	Trekrone/skygg
260	8	2	FD Legde. Gbnr 1016/1 Larvik	Legde
261	11	1	FD Tak. Gbnr 137/6 Sandefjord	Hus/bygning
262	9	2	FD Trekrone/skygge. Gbnr 1080/1 Larvik	Trekrone/skygg
263	7	1	FD. Trekrone/skygge. Gbnr 127/1 Sandefjord	Trekrone/skygg
264	8	1	FD. Sandfelle golfbane. Gbnr 137/6 Sandefjord.	Sandfelle
265	7	1	FD. Tak. Gbnr 139/34. Sandefjord.	Hus/bygning
266	7	2	FD. Usikker årsak/svak ring. Gbnr 149/6 Sandefjord.	Usikker årsak
267	7	1	FD. Usikker årsak. Gbnr 2042/160. Larvik	Usikker årsak
268	7	2	FD. Traktorspor. Gbnr 1072/5 Larvik	Traktorspor

269	7	2	FD. Usikker årsak. Gbnr. 148/1,5 Sandefjord.	Usikker årsak
270	11	1	FD. Golfgreier. Gbnr.137/13 Sandefjord	Sandfelle
271	7	1	FD. Kjørespor i åker. Gbnr 1083/1 Larvik.	Traktorspor
272	7	1	FD. Trekrone/skygge. Gbnr 2034/2 Larvik.	Trekrone/skygg
273	7	2	FD. Trekrone/skygge. Gbnr 1009/1 Larvik.	Trekrone/skygg
274	7	1	FD. Ranke med stubb. Gbnr 138/5 Sandefjord	Ranke
275	7	1	FD Usikker årsak. Gbnr 1021/1 Larvik.	Usikker årsak
276	9	2	FD. Treskygge/krone. Gbnr 2043/8	Trekrone/skygg
277	7	2	FD. Deteksjon mellom traktorspor. Gbnr 146/1 Sandefjord.	Traktorspor
278	7	1	FD. Usikker årsak. Gbnr 147/39	Usikker årsak
279	9	1	FD Legde. Gbnr.147/39 Sandefjord	Legde
280	9	2	FD. Usikker årsak. Gbnr 2026/1 Larvik MEN 200 meter vest for 280 ligger Skauen gravfeltet (som har fallt ut av Askeladden, melder fra RA) Tydelige overpløyde graver vest og nord for gravfelt, usikkert antall 5? Gbnr 2027/3	Usikker årsak
281	9	1	FD Trekrone/skygge. Gbnr 141/1 Sandefjord.	Trekrone/skygg
282	7	2	FD. Usikker årsak. Gbnr 2045/1 Larvik	Usikker årsak
283	7	1	FD. Crossbane, gbnr 150/12, Sandefjord.	Motorcrossbane
284	10	2	FD. Trekrone/skygge gbnr.151/1,3 Sandefjord	Trekrone/skygg
285	7	1	FD. Åkerholme gbnr 141/4 Sandefjord.	Åkerholme/bergskjær
286	8	1	FD. Sandfelle golfbane gbnr. 137/6 Sandefjord.	Sandfelle
287	9	2	FD. Skygge/trekrone. Gbnr 1039/1 Larvik.	Trekrone/skygg
288	8	1	FD usikker/svak deteksjon på gbnr. 1109/2 Larvik.	Usikker årsak
289	7	2	FD usikker deteksjon. Gbnr 2034/10 Larvik	Usikker årsak
290	7	1	FD Usikker årsak. Gbnr 1109/1	Usikker årsak
291	12	1	FD trekrone. Gbnr 1043/2,3,9	Trekrone/skygg
292	7	1	FD Usikker årsak/svak ring. Gbnr 2045/24 Larvik	Usikker årsak
293	7	2	FD Trekrone/skygge gbnr. 1092/6 Larvik	Trekrone/skygg
294	7	2	Mulig deteksjon. Svak ring. Gbnr,123/1 Sandefjord.	Usikker årsak
295	7	2	FD. Legde. Gbnr 1010/4 Larvik	Legde
296	7	2	FD Trekrone/skygge gbnr 1097/2 Larvik.	Trekrone/skygg
297	7	1	FD Trekrone/skygge gbnr 159/9 Sandefjord.	Trekrone/skygg

298	7	1	FD. Trekrone/skygge gbnr 159/9 Sandefjord. MEN 260 m VSV for 297 ligger en mulig grav sees som en sirkulær flate om lag 22 m i diameter. Ikke detektert av CS. Ligger på gbnr. 153/10,11 på koordinater 6556265.05 N og 566106.28 E.	Trekrone/skygg
299	9	1	FD. Tak. Gbnr 1071/6, Larvik.	Hus/bygning
300	7	1	FD Usikker årsak. Gbnr 1083/1 Larvik.	Usikker årsak
301	8	1	FD Usikker årsak. Gbnr 1083/1 Larvik	Usikker årsak
302	7	1	Mulig deteksjon, usikker, svak ring i svært drenert åker. Gbnr 1086/2. Larvik.	Usikker årsak
303	8	2	FD Trekrone/skygge gbnr 1027/2. Larvik	Trekrone/skygg
304	7	1	FD. Åkerholme gbnr. 139/5 Larvik.	Åkerholme/bergskjær
305	9	2	FD. Legde gbnr 1035/2, Larvik.	Legde
306	7	2	FD. Trekrone/skygge gbnr.2042/15 Larvik.	Trekrone/skygg
307	9	2	Positiv deteksjon. Svak ring. Gbnr 121/35 Sandefjord kommune. Ligger innenfor lokalitet på Virik.	Fotgrøft
308	7	1	FD Trekrone gbnr 2041/ Larvik	Trekrone/skygg
309	7	1	FD Svak ring, usikker. 1109/2 Larvik	Usikker årsak
310	7	1	Mulig deteksjon. Svak ring. Ligger ytterligere en svak ring NNV for 310. På gbnr. 1035/1 Larvik.	Usikker årsak
311	9	2	FD. Usikker årsak. Gbnr 141/18	Usikker årsak

4.3 Tønsberg

The satellite image assessed by the Norwegian Institute for Cultural Heritage Research (NIKU) covers an area to the northwest of Tønsberg and constitutes parts of Tønsberg, Horten, Re and Stokke municipalities in Vestfold County. The area covers approximately 150 m² (see Chapter 3 for more details) and the Askeladden database of scheduled monuments shows a relatively high proportion of cultural heritage sites within the four municipalities.

The image has been processed by the Norwegian Computing Centre (NR), resulting in a total of 2381 detections (Figure 48 – Figure 49). All detections have been assessed by an archaeologist at NIKU, but none have been classified as positive.

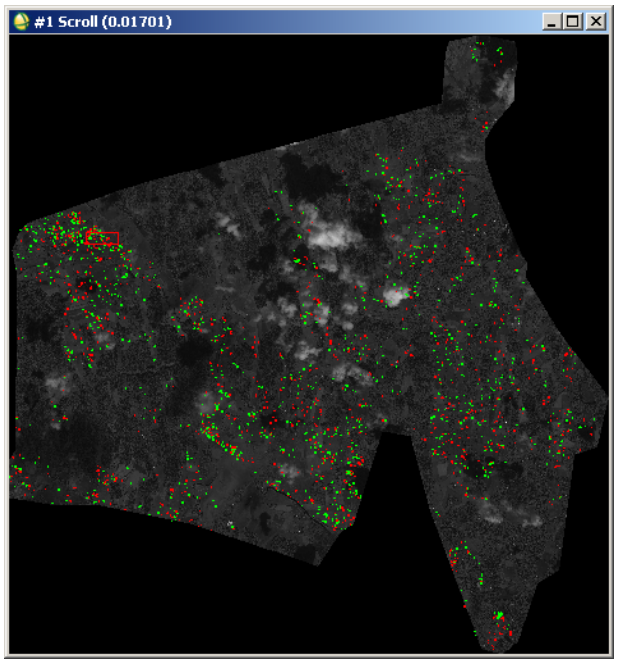


Figure 48. Image showing all 2381 detections in the processed image. Note the high number of detections in the northwestern part of the image and the lack of detections in the adjoining area to the east.

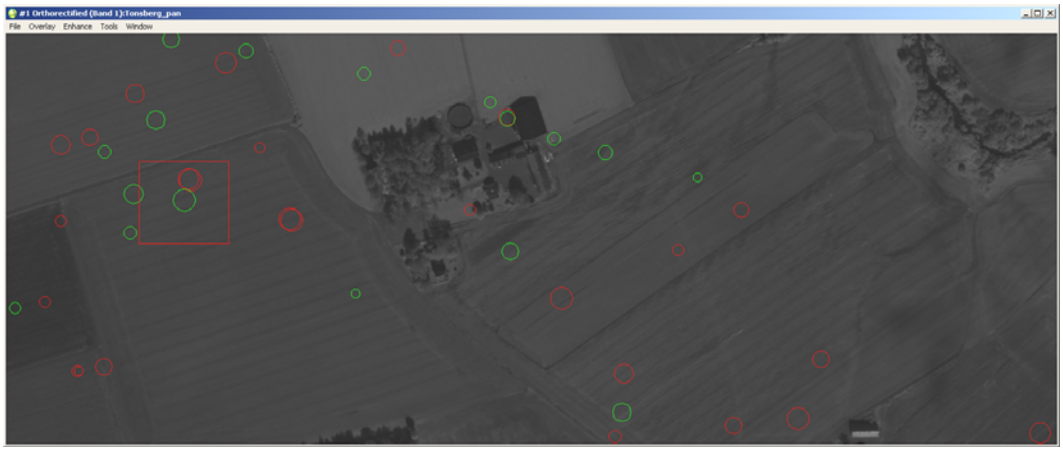


Figure 49. Detail of processed image with detections, corresponding to the red rectangle in Figure 48. Note the apparent random scatter of detections and the presence of circular and sub-circular features.

The discrepancy between the high number of detected features and lack of positive detections was somewhat surprising, given that the processing has proven relatively successful with other

satellite images. It was therefore decided to cursorily inspect the entire image visually in order to determine whether the image itself was the cause of this.

The visual inspection showed that, compared to the other images, there are relatively few suitable targets for detection in the Tønsberg image. Nevertheless, some circular features have been observed (Figure 50 – Figure 52). These circular and sub-circular features have not, however, been detected by CultSearcher. The visual inspection also indicated that the image should be suitable for detecting crop marks, as other features such as hollow ways and drainage ditches could be observed.

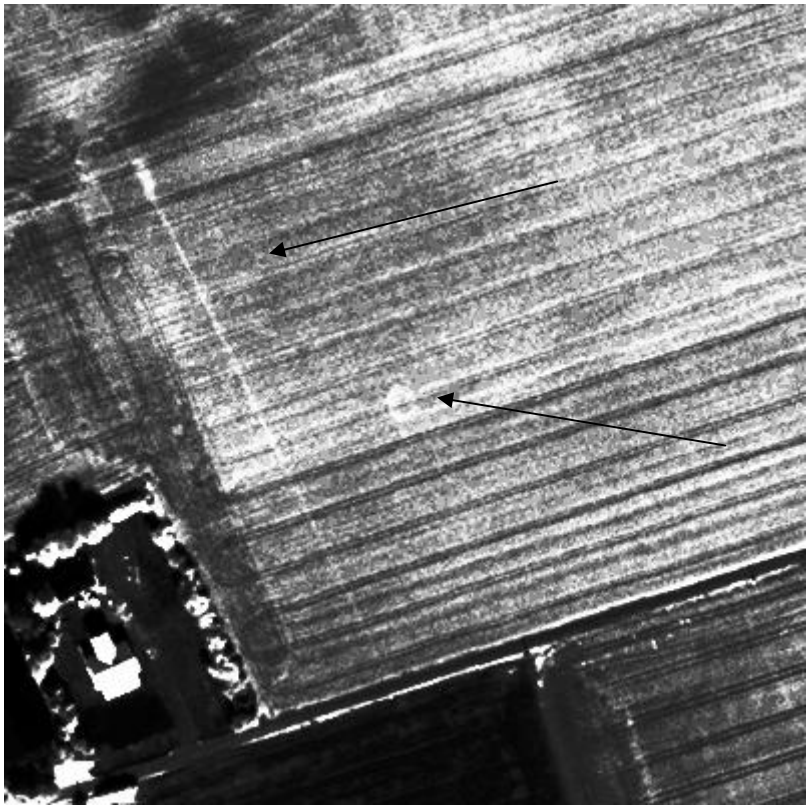
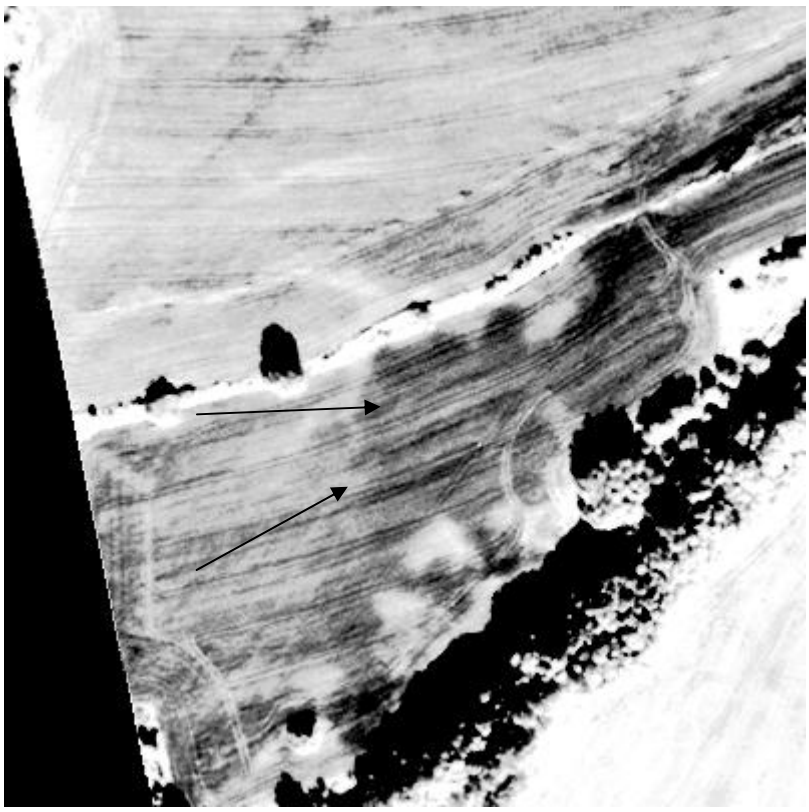


Figure 50. Two possible crop marks observed visually at 571993E/657983N (3506,9121). Diameter 10 – 11m.



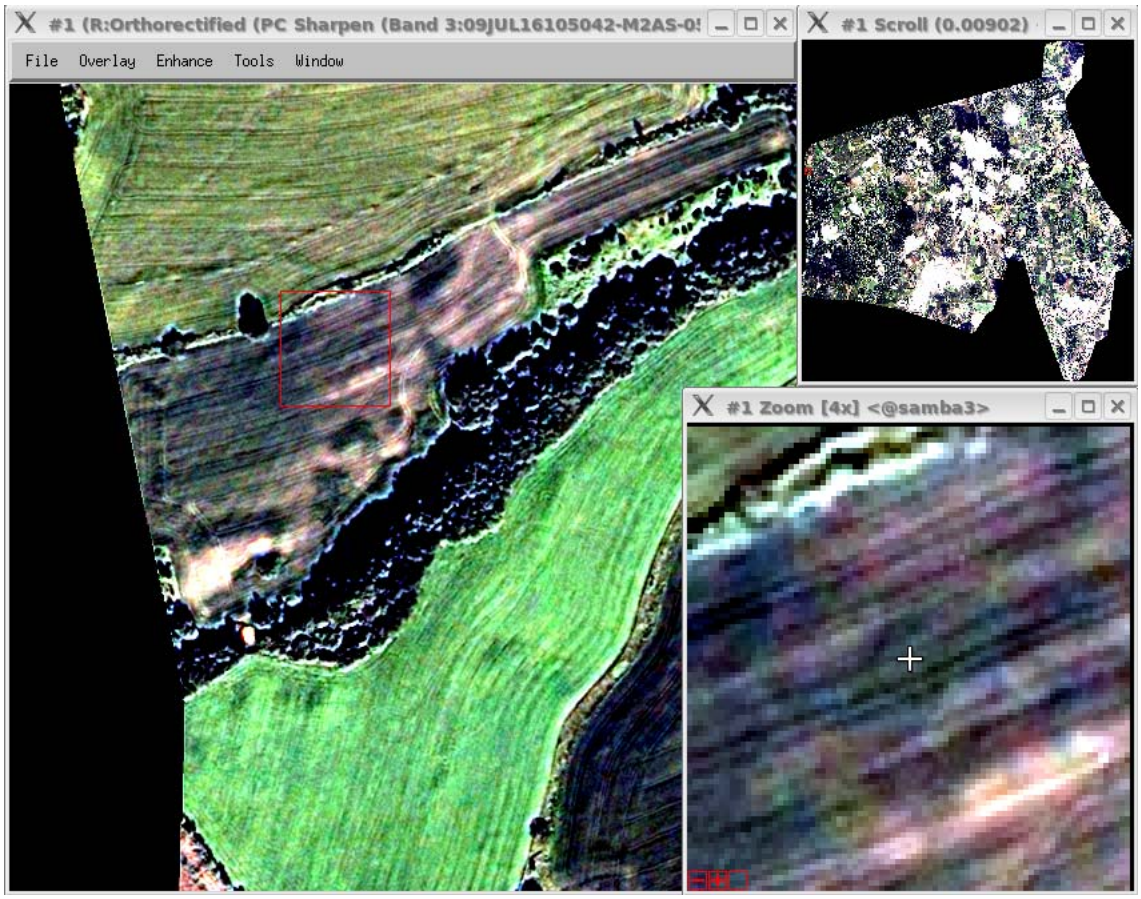


Figure 51. Two or three indistinct crop marks observed visually at 570169E 6578873N (467,10788).

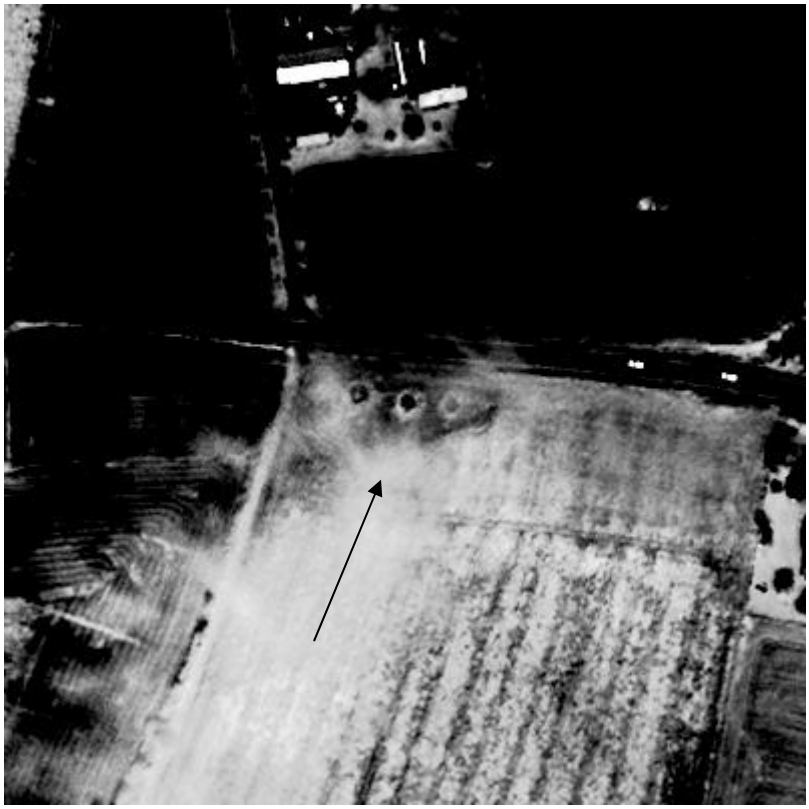


Figure 52. Three distinct crop marks visually observed at 570700E 6573221N (1352,20206).

Experience gained from the validation of other satellite images indicates that the detection of circular, but non-archaeological features is rather common. In those cases, however, it is easy to understand why the software has detected a feature and the archaeologists can ignore those detections. The detections in the Tønsberg image on the other hand seem almost random, and the detections cannot be easily explained. Additionally, as figure 1 demonstrates, there is a high concentration of detections in some parts of the image while there is a complete lack of detection in others.

The fact that the software has failed to detect any crop marks in this image despite the presence of suitable targets, might indicate that the image processing is at fault and not the image itself. It is therefore recommended that the image processing be assessed in order to find a more suitable detection procedure.

4.4 Hedrum, Sandefjord and Stavern

The Museum of Cultural History (KHM) has participated by validate and verifying results from the CultSearcher. We refer to previous reports and elsewhere in this paper for descriptions of the ENVI and CultSearcher software and the use of the satellite images in general. The results of the verifications of the detected objects made by CultSearcher are presented here.

The areas for KHMs analysis were approx 75 km^2, and contained satellite images of three regions in the south of Vestfold County; Hedrum and Stavern (Larvik municipality) and Sandefjord municipality (for details about the images se chapter 3). The images had been processed by Norsk Regnesentral (NR). CultSearcher detected 127 objects in total in these three satellite images. None of the detected circular objects had previous been recorded and vis-versa. The detections can be divided in to three categories; positive, possible and negative. None of the detections can positively be placed in the positive category. Nine (9) detections (3 from every image) were defined as possible cultural heritage site. They are all interpreted as possible ring ditches from deleted prehistoric graves. These should be target for further investigations. The rest, 120 detections, were negative. This gives in total that 7 % of the detections could be interesting for further investigation.

Table 4.Detections made by CultSearcher and verified by visual inspection by archaeologists.

Image name	CultSearcher detection no	Interpretations	Comments
Hedrum	1	Possible ring ditch	Possible ring ditch. Image some unclear. Object is situated approx. 180 m SSE of known burial field (Askeladden ID90983) Could be tracks from a tractor/plowing turnover .
Herdum	3	Possible ring ditch	Another undetected ring ditch is observed south of this one.
Hedrum	17	Possible ring ditch	The detection is situated approx. 90 m NNW of a known deleted grave mound (Askeladden ID90714). Approx 45 m to the SW of this detection, another not-detected ring is observed.
Stavern	6	Possible ring ditch	Very vague detection.
Stavern	12	Possible ring ditch	Another 2 or 3 possible ring ditches is observed nearby. Possible part of an unknown burial ground. The detection is situated 450 m S of the known burial field containing 6 grave mounds (Askeladden

Image name	CultSearcher detection no	Interpretations	Comments
			ID106613).
Stavern	13	Possible ring ditch	Possible part of a unknown burial ground.
Sandefjord	6	Possible ring ditch	Vague detection. Possible other ring ditch to the NE and ESE.
Sandefjord	13	Possible ring ditch	Several more possible ring ditches nearby.
Sandefjord	75	Possible ring ditch	Close to known site. Unclear image.

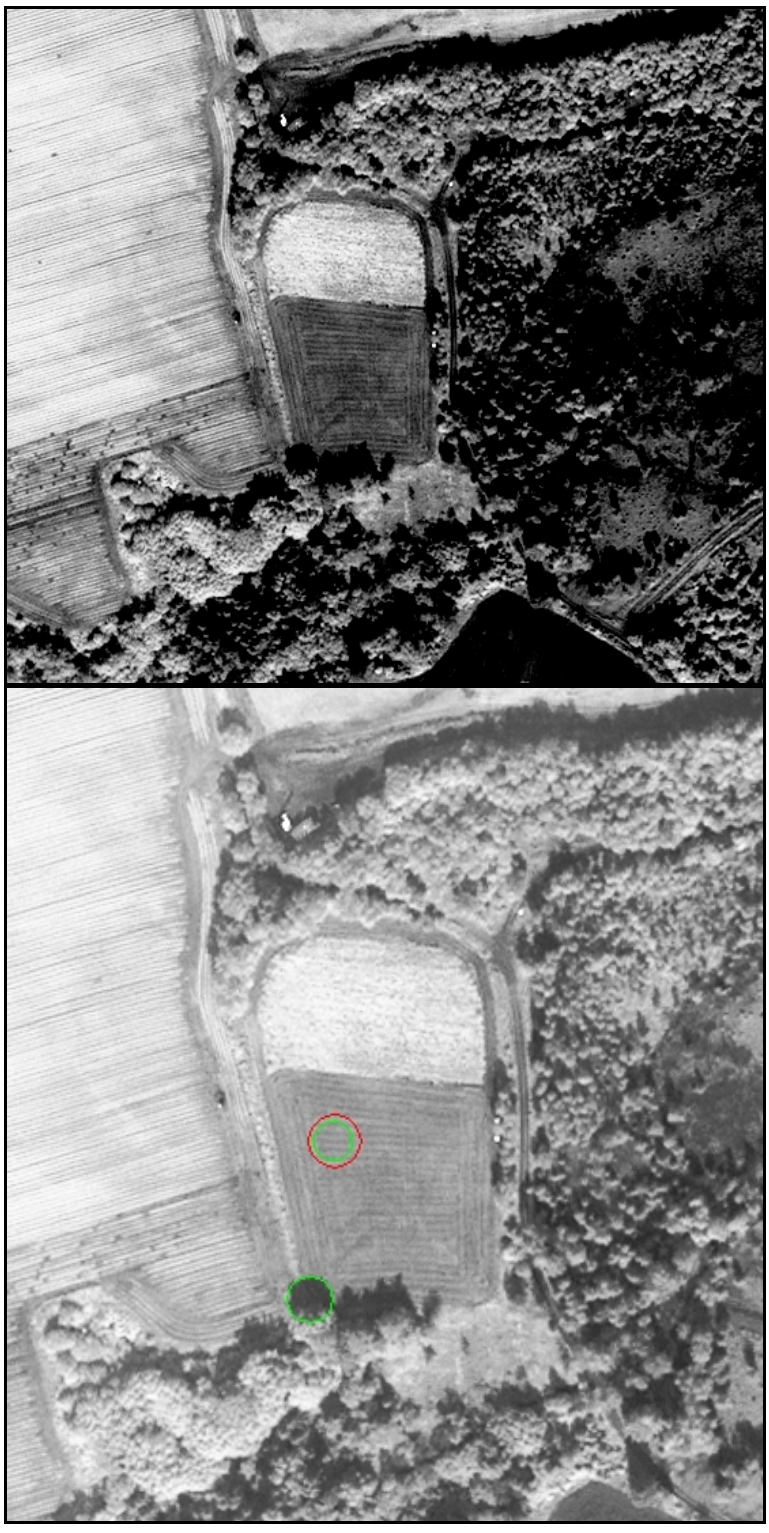


Figure 53. Hedrum no 1. Possible ring ditch. A known burial field (Askeladden ID90983) is situated approx. 180 m to the SSE. Could be tracks from a tractor/plowing turnover.

Figure 54. Pansharpened color image of detection No. 1 in the Hedrum image.

Figure 55. Hedrum no 3. Possible ring ditch detected by CultSearcher. Undetected possible rings ditch is observed south of this one (black arrows).

Figure 56. Pansharpened color image of detection No. 3 in the Hedrum image.

Figure 57. Hedrum no 17. Possible ring ditch detected by Cultsearcher. Approx 90 m to the ESE is the, now deleted, grave mound ID90714 situated. Possible other ring ditches are located to the SE and SSE. Arrows indicates the undetected rings.

Figure 58. Pansharpened color image of detection No. 17 in the Hedrum image.

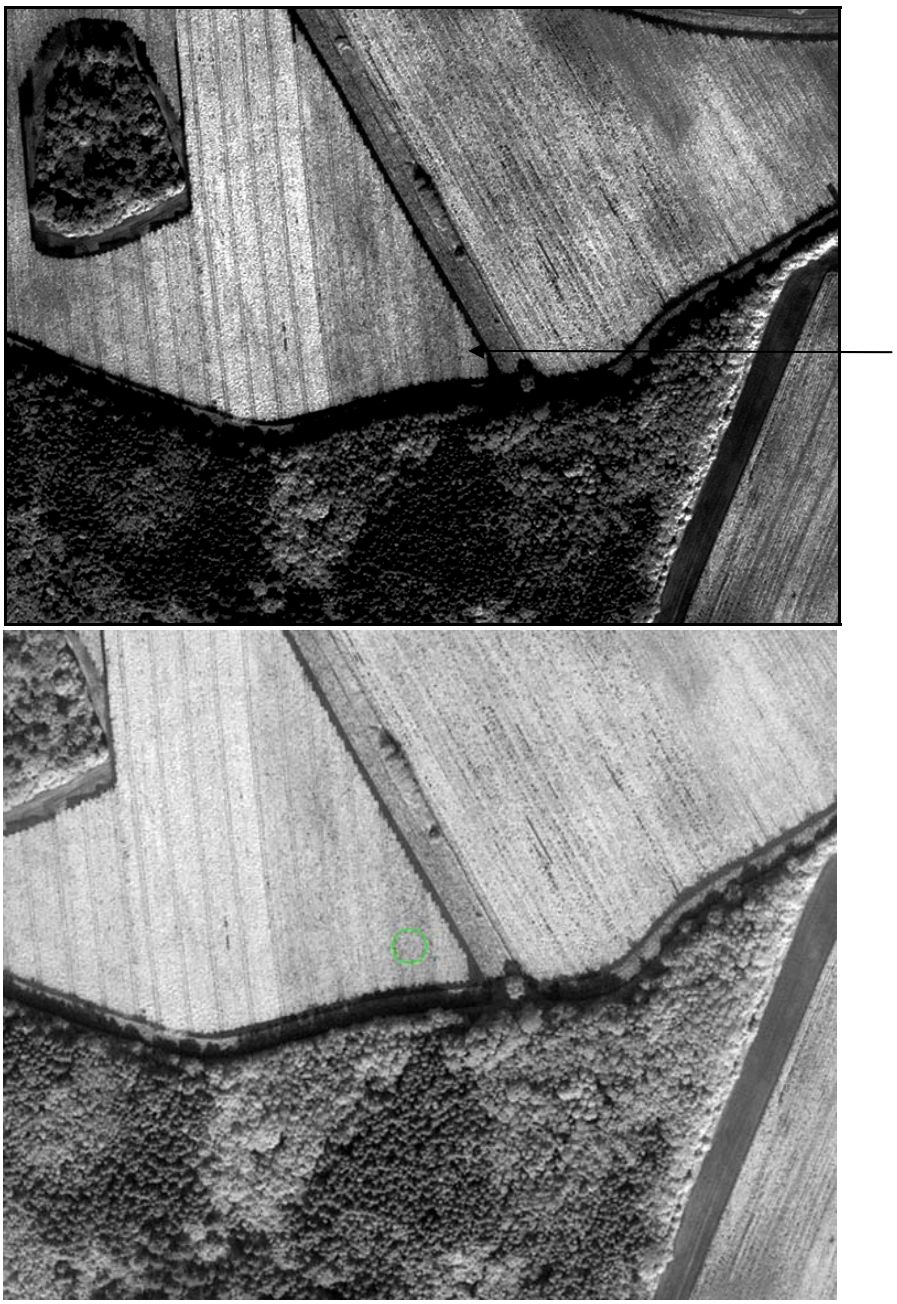


Figure 59. Stavern no 6. Possible ring ditch. The detection is very vague.

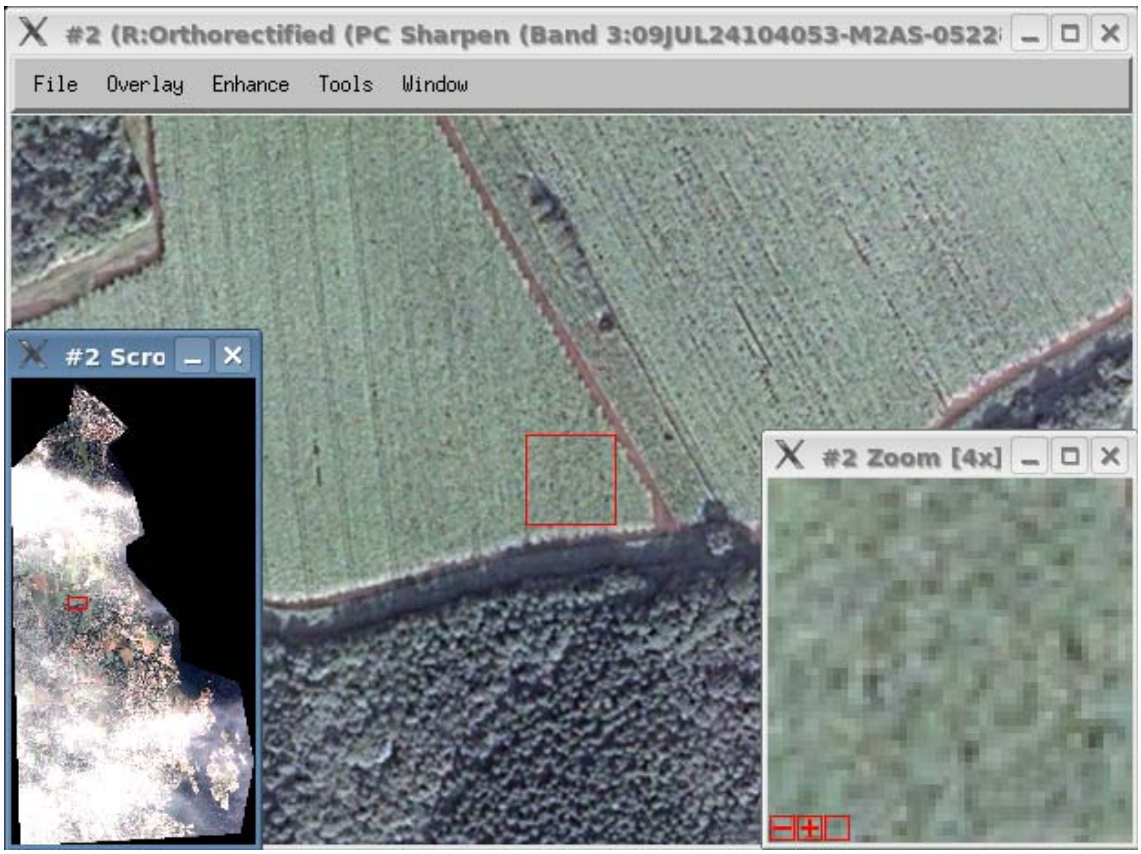


Figure 60. Pansharpened color image of detection No. 6 in the Stavern image.

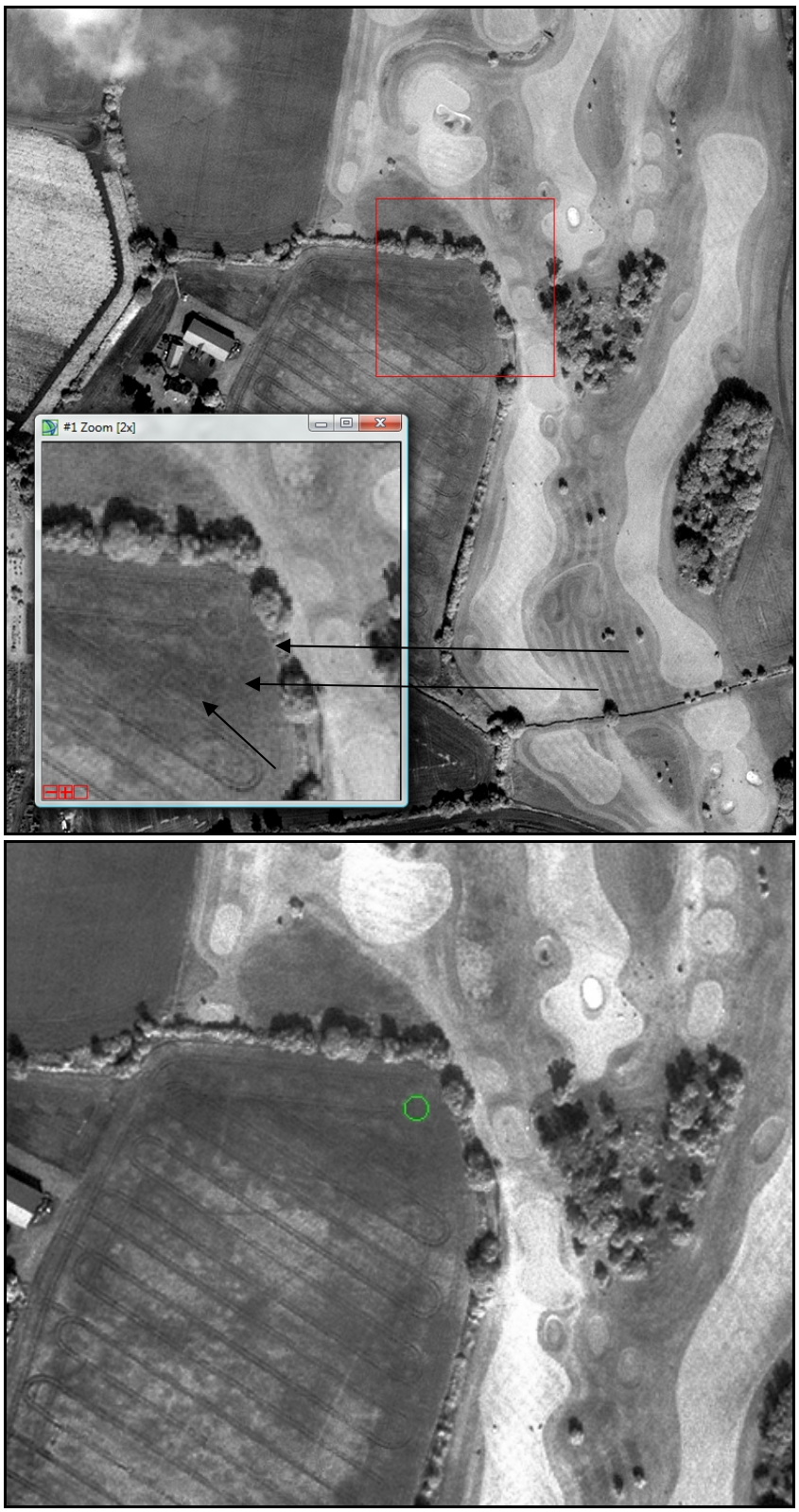


Figure 61. Stavern no 12. Possible ring ditch. In addition to the detected ring there can be observed several other rings south of the detected ring. This could be remains of a deleted pre historic burial ground. Arrows indicate the undetected rings.

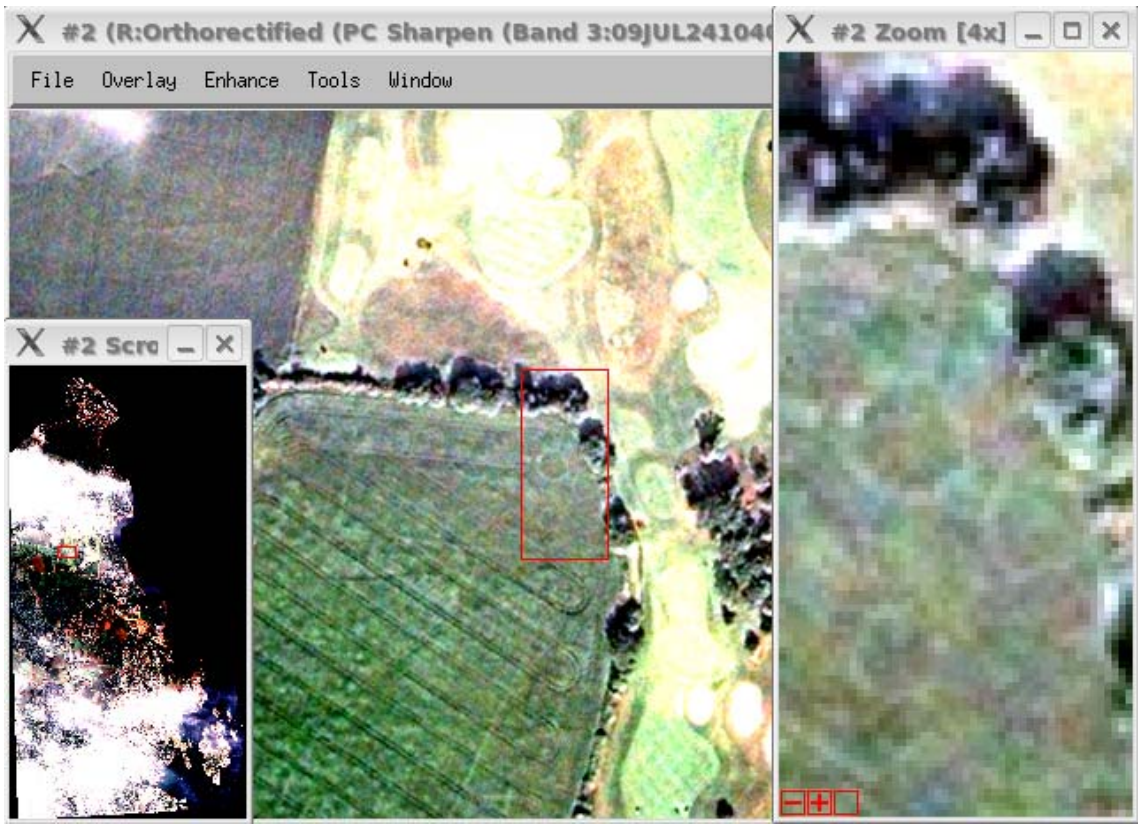


Figure 62. Pansharpened color image of detection No. 12 in the Stavern image.

Figure 63. Stavern no 13. Ring ditch detected by CultSearcher. To the NE can possible undetected ring ditches be observed (black arrows).

Figure 64. Pansharpened color image of detection No. 13 in the Stavern image.

Figure 65. Sandefjord no 6. Possible ring ditch. This detection is vague. There can also briefly be observed possible rings slightly to the NE and ESE of the detected object (black arrows). It could be remains of a deleted burial ground.

Figure 66. Pansharpened color image of detection No. 6 in the Sandefjord image.

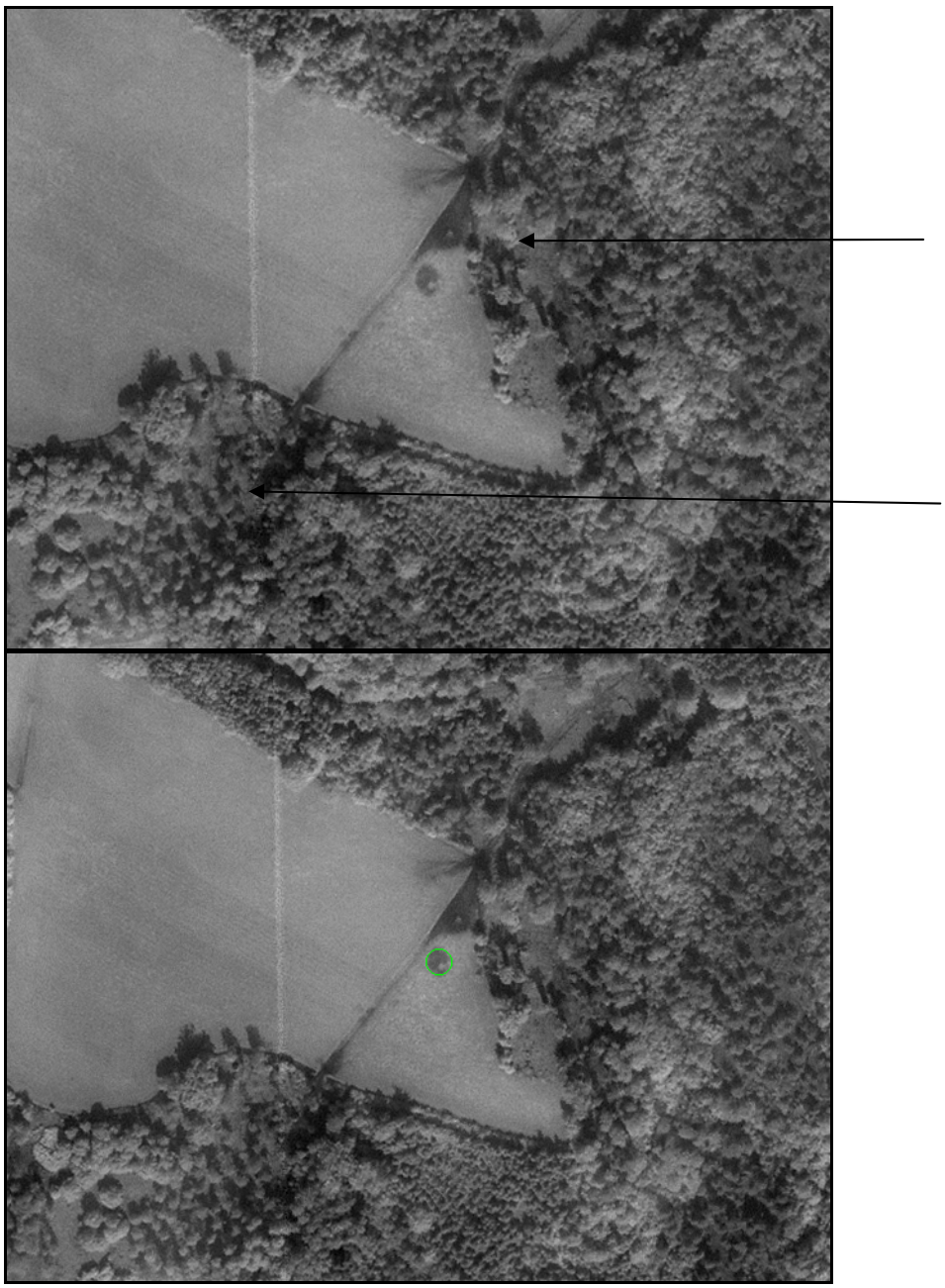


Figure 67. Sandefjord no 75. Possible crop marks. It could derive from prehistoric grave. North of the detection is a known grave mound to the N (Askeladden ID20179) and there are several numbers of known grave mounds to the S (Askeladden ID108122).

Figure 68. Pansharpenec color image of detection No. 75 in the Sandefjord image.

4.4.1 Examples of negative detections from Hedrum, Sandefjord and Stavern.

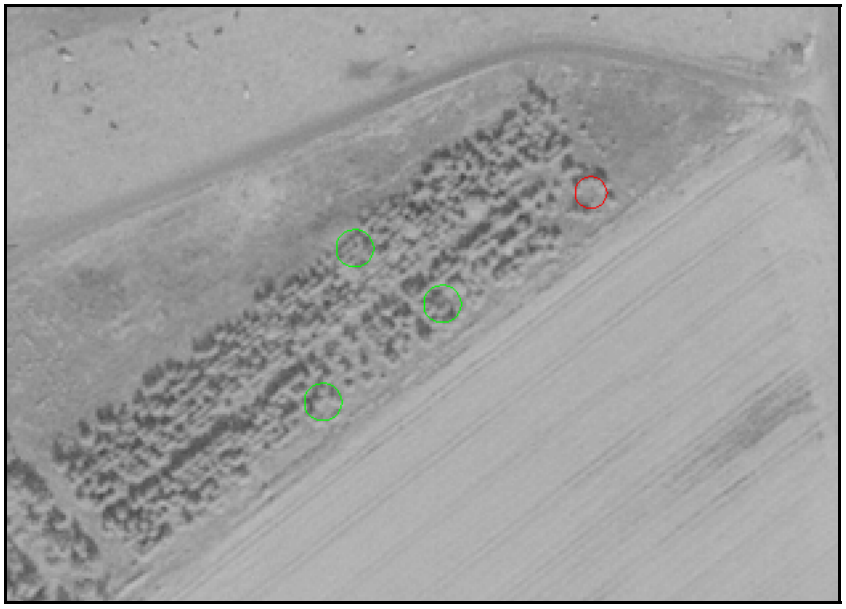


Figure 69. Sandefjord no 7, 8, 72 and 73. Negative detection in forest – low vegetation.

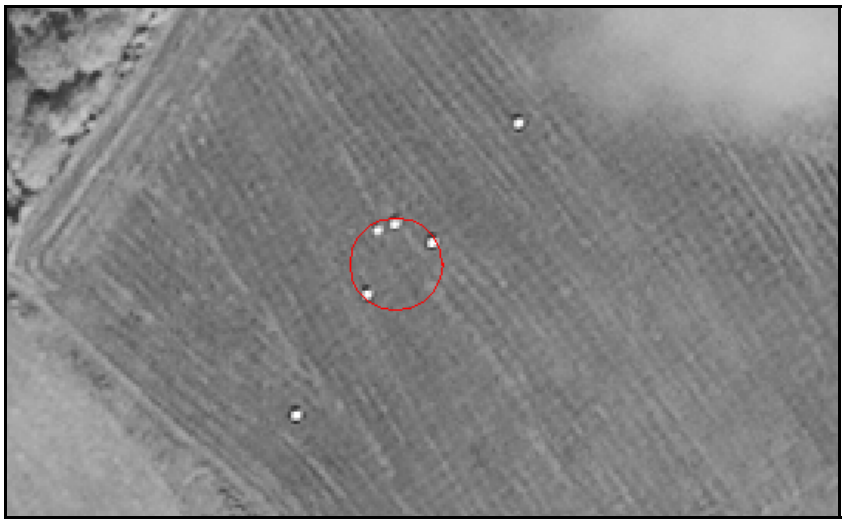


Figure 70. Sandefjord no 30. Negative detections on cultivated field. The white objects are presumed to be hay packed in white plastic.

Figure 71. Hedrum no 18. Negative detection made by CultSearcher. The object is a three and its shadow into the cultivated field.

Figure 72. Hedrum no 2. Negative detection made by CultSearcher. The detection is plow marks.

4.4.2 Example of not-detected objects from Hedrum, Sandefjord and Stavern

There have not been time to do a complete manually scan of the satellite images. The two examples below were observed by the archaeologist while verifying the CultSearcher detections nearby.

Figure 73. Hedrum. Several clear defined circular objects (black arrows). This is an area of deleted pre historic grave mounds that have not been registered in the Askeladden data base (It's however observed from aerial photo in 2001. (Christer Tonning ref.)). The white arrow indicates a rectangular object observed SE of minimum two circular objects. This could indicate ditches related to a house. Position: n:6554899, E:560011, WGS1984/UTM32.

Figure 74. Pansharpened color image of parts of Figure 73.

Figure 75. Hedrum north. Undetected ring shaped object. Possible ring ditch indicating deleted pre historic grave mound. Position: n:6557529, E:558720, WGS1984/UTM32.

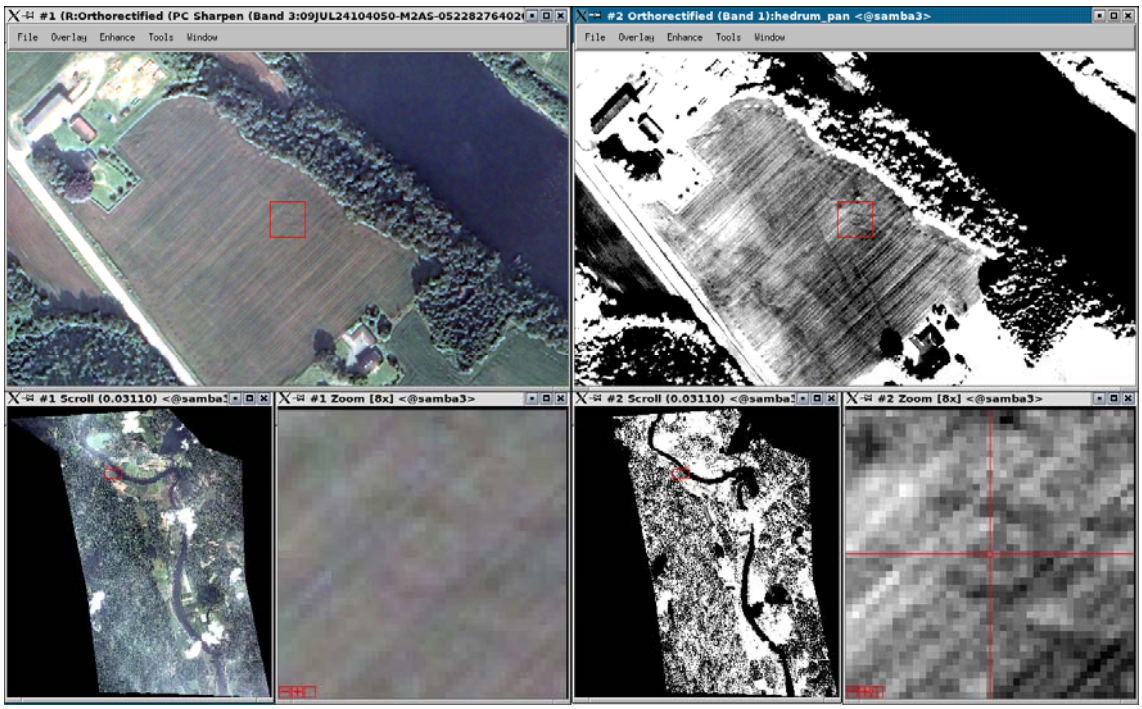


Figure 76. Contrast enhanced color and panchromatic images of the ring shaped object in Figure 75.

4.4.3 Museum of Cultural History; some comments on CultSearcher

The participants from the Museum of Cultural History (KHM) had no experience neither with CultSearcher nor ENVI software prior to this task. For KHM, the testing has also been a test of the usability of the tools for validation and verification of the CultSearcher detections. We will therefore ad some comments to the process from the installation of the software to the verification of the detections.

- **Installing CultSearcher.** The software installation required that the data folder had been copied to the C: drive. At KHM (and University of Oslo, we assume) it is just IT-administrators that have access to the system drive. The data folder was placed on D: drive instead, but CultSearcher gave no possibility to browse to the D: drive. The only option was the C: drive. We had to get administrator's rights to copy to the C: drive, install CultSearcher and then remove the data away from C: drive back to D: with the result that when opening for data in CultSearcher it is always the C: drive folder that opens. This made the installation more tricky then necessary and more unnecessary browsing to correct folder each time new images had to be opened, etc.

- **_rings.txt.** We could not get any tables of detected object to appear. The reason to this was that we had to change the path inside the _rings.txt-file. This because the detection had been done on computers at NR and that the file needs the correct heading/path to work. We solved this after remembering an email from Due Trier regarding this. Our mistake.

- **Enhance image.** Learning how to enhance the image the best way took some time. One problem was that we could not find any way to reset the image after enhanced, and after some attempt with different methods for enhancement, the image went total black or white and we had to start from the beginning with re-opening the image. Some times when we had linked the panchromatic image with the RGB-image and the RGB became

useless in the sense that it was too dark or too light. We mostly used "sharpen (18) filter" and Gaussian when verifying the CultSearcher detections.

- **Floating windows.** Working with the panchromatic image, RGB-image, table, color table gives approx 12 windows to work with. If you also have ArcGis and Internet for alternative information ("Askeladden", Norge i bilder)) available and maybe a text- or database program for noting your comments about the detections. You are then having a large number of windows to control and it makes the workflow complex. The scroll and zoom-windows does not appear automatically when restoring the panchromatic image. You must right click and choose position for the scroll and zoom window every time you have been using another application. If you are working on a single screen it could be difficult to find an effective workflow, at least at our stage of testing CultSearcher/ENVI

- **Detections on/off.** We miss the possibility to switch the detected rings on/off without removing the ROI.

- **Instructions.** We assume that some more training from the project to the representatives from KHM many of the above mentioned issues could have been avoided. However, we are of the opinion that at this stage using CultSearcher and ENVI software will demand quit some It- and GIS-skills.

5 Visual inspection of archive Sør-Trøndelag images

5.1 The Kvenild-image, acquired 22 April 2008

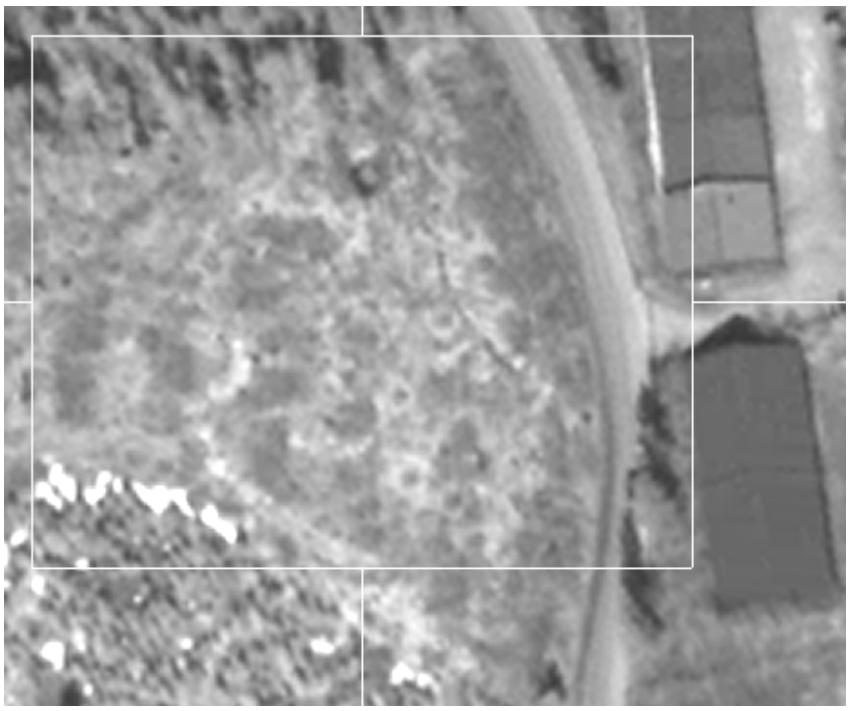


Figure 77. At least 4 tar-pits, features visible on surface. Bog. Tiller, gnr 326/36 Trondheim kommune. Visible also on orto10, 10 May2008.

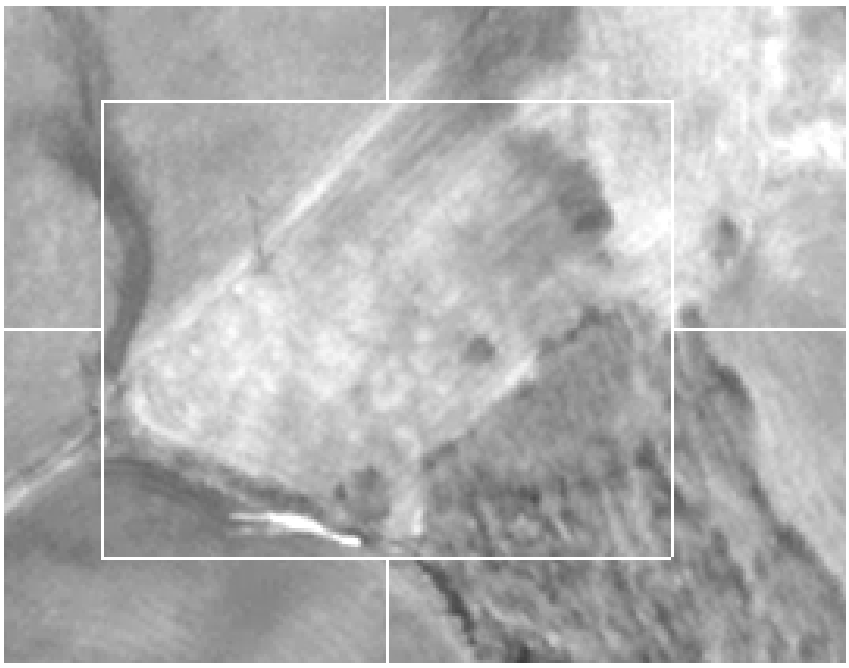


Figure 78. Possible plowed-over tar-pit (dark spot near center of image) + light rings, soilmarks. Tiller, Erikgården, Trondheim kommune gnr 329/4. Cultivated bog-area. Visible also on orto20, 20 July 2006.

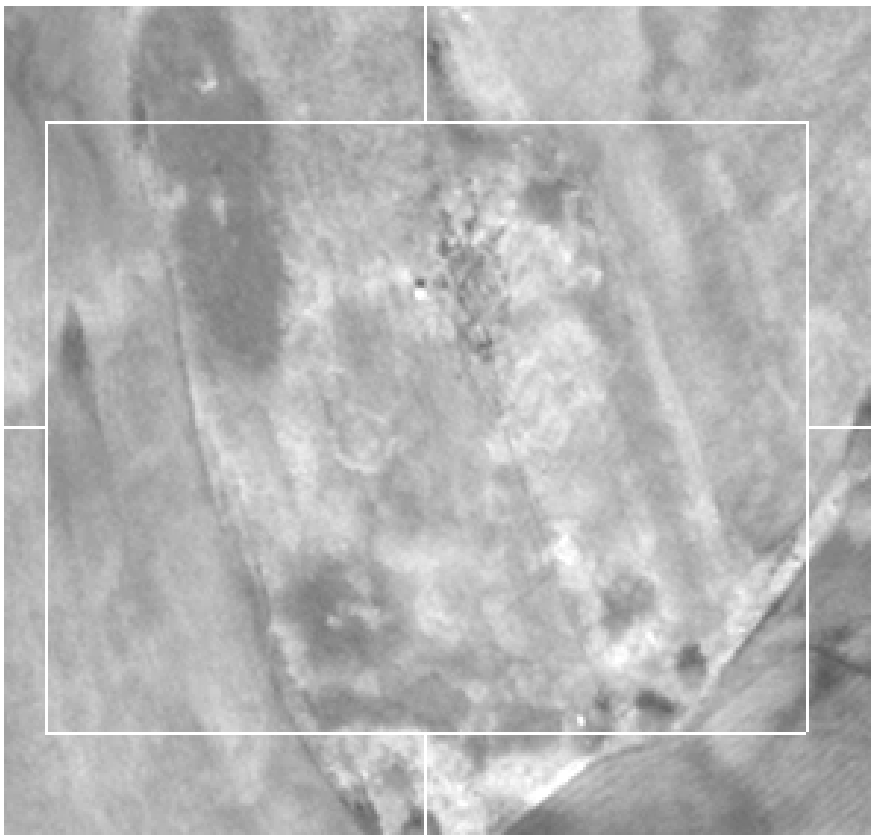


Figure 79. Ring-structures, cropmarks at Kvenild, gnr 313/1, Trondheim kommune. Visible also on orto10 and orto20. Also detected by CultSearcher (the Melhus-image).

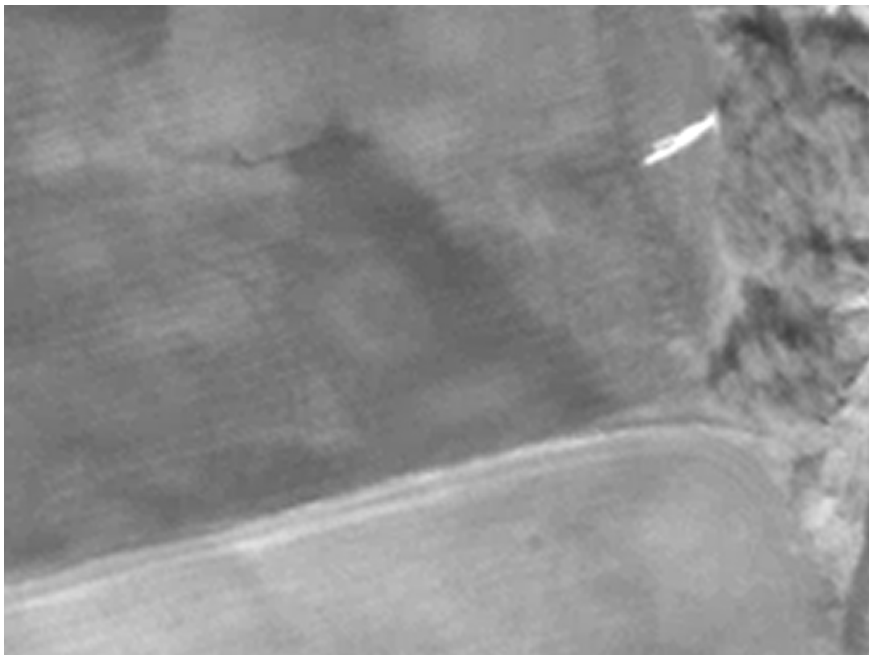


Figure 80. Ring-structure, soilmark at Torgård, gnr 310/1, Trondheim kommune. Not visible on ortophoto.

Figure 81. Ring-structures, cropmarks at Øye, gnr 1/7, Melhus kommune. Not visible on ortophoto.

5.2 The Ørland-image, acquired on 7 August 2004

Figure 82. Ring-structure, cropmark at Rabban, gnr. 76/16.

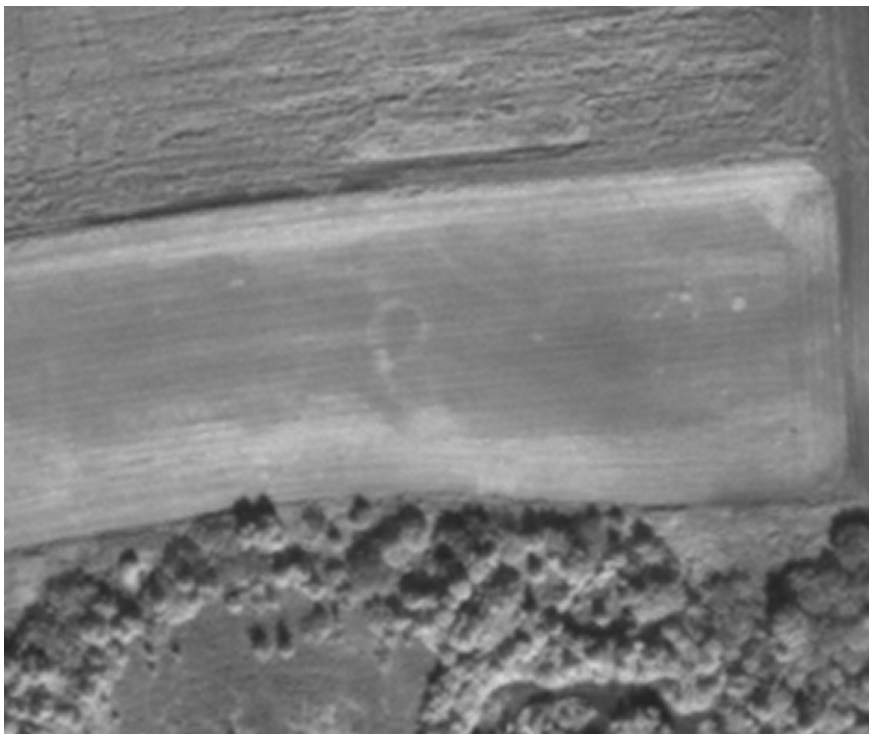


Figure 83. Ring-structure, soilmark at gnr. 72/29.

Figure 84. Circular dark spots at Litljmyra, gnr. 75/2.

The circular dark spots at Litjmyra (Figure 84) are also visible on ortophoto aquired two months earlier the same year (Figure 85).

Figure 85. Orthophoto of the same area as in Figure 84.

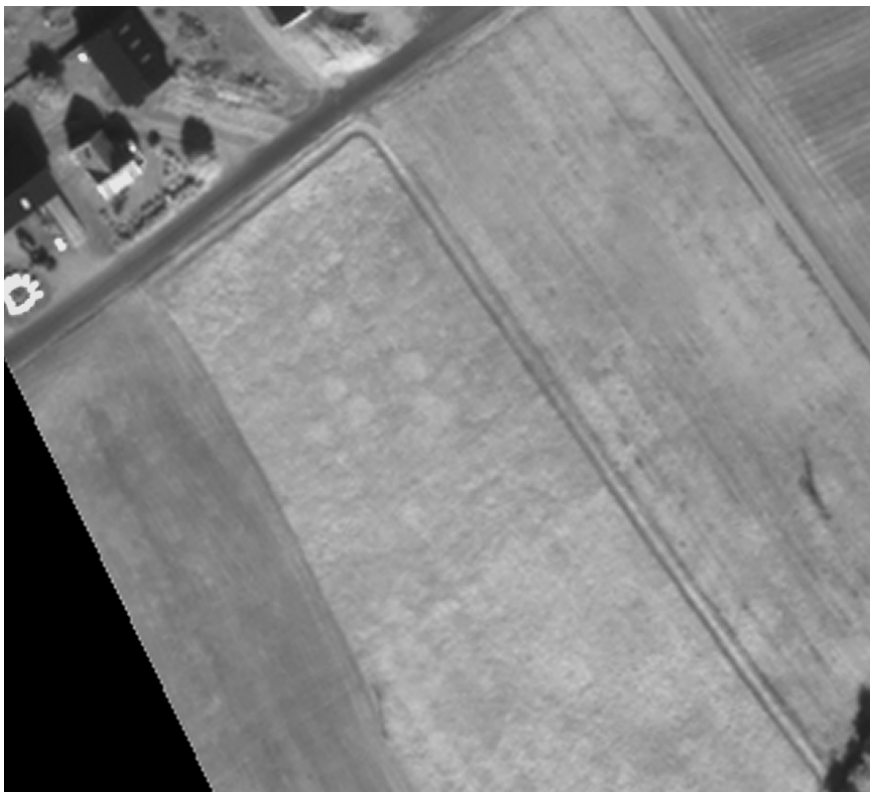


Figure 86. Faint traces, possibly crop marks. Several possible rings at Uthaug.

Figure 87. Aune, gnr. 71/24. Circular dark spot + several oblong spots, soilmarks.

Figure 88. Fagertun, gnr. 71/15, 1 light ringstructure, + several dark ones, cropmarks.

Figure 89. Faint ringstructure, cropmark, not far away from registered gravemound.

Figure 90. Fagerlund/Østlund Fitjan, 2 dark spots, possibly feedingstations for cattle.

Figure 91. Hårberg, gnr 70/2, ringstructures, longbarrow and possible houseground, soilmarks.

5.3 The Melhus-image, acquired on 11 October 2002

Figure 92. Holem, several faint ringstructures, soilmarks. Also visible on ortophoto.

5.4 Conclusions

Several possible archaeological sites were found during the visual inspection of the provided images. None of the above mentioned examples have previously been registered as sites. Interestingly, it is possible to identify tar-pits located in bog-areas, a site category which is well represented in Trøndelag. The Melhus-image yielded only a few detections, probably due to the late date of the satellite image acquisition. Most fields were harvested, but not yet ploughed, thereby removing the possibility of both soil marks and crop marks. Spring and/or late summer/early autumn like in the two other images seem to be better times to look for sites in cultivated land. Tar-pits in bog may be located at other times, provided there is no snow-cover.

6 User interface improvements

The user interface has been simplified to focus on ring search and subsequent validation. All mention of amorphous objects have been removed from the main menu and the main dialog (Figure 93).

Figure 93. Left: the main menu in CultSearcher. By selecting "interactive ring search, the main dialog appears. Right: The main dialog is used to start a new ring search or to validate a previous ring search.

When ring search is selected, the user only has to specify the directory in which the input image resides. The directory name is also the prefix of the filename to all files in that directory. The file postfixes are as follows.

_pan / _pan.hdr	panchromatic input image in ENVI format and associated header file
_msk / _msk.hdr	Agricultural mask image
_rings.txt	Text file with detected rings
_valid_rings.txt	Text file containing the rings that were accepted during validation.

When starting a ring search, the _pan, _pan.hdr, _msk and _msk.hdr files are required. The other files are output files. In addition, intermediate files are produced.

The results of a ring search are stored in a text file (Figure 94) containing the following information.

- CaseDir : full path name to directory
- CaseName: prefix of filename
- The parameters used during ring search
- A list of detected rings. For each ring the coordinates are given, and also the radius and if it is dark or bright. It is possible to set a parameter in the advanced parameter settings to also list all pattern recognition features for each ring.

```
Ring search:
caseDir =
/nr/samba/jo/pro/CultSearcher/Usr/Siri/CultSearcher09/Data/laagen_small
caseName = laagen_small

Parameters for search:
minRadius = 4
maxRadius = 10
radSpacing = 0.600000
max number of rings = 1000
minSimilarity = 50
marginFactor = 1.20000
ringWidth = 2.50000
widthOffsetFactor = 0.750000

nofCircles = 153
circleFeatures = {
1459.00 513.000 6.66667 1.00000,
725.000 699.000 7.66667 2.00000,
724.000 698.000 12.6667 1.00000,
1460.00 514.000 13.6667 2.00000,
656.000 605.000 12.6667 1.00000,
657.000 604.000 6.66667 2.00000,
622.000 759.000 6.66667 2.00000,
582.000 680.000 6.66667 2.00000,
1228.00 1108.00 8.66667 2.00000,
504.000 691.000 6.66667 2.00000,
675.000 1103.00 6.66667 1.00000,
558.000 135.000 6.66667 1.00000,
977.000 501.000 6.66667 1.00000,
1528.00 630.000 6.66667 2.00000,
287.000 896.000 6.66667 1.00000,
441.000 772.000 6.66667 2.00000,
……
```

Figure 94. Text file containing ring search result.

6.1 Validation

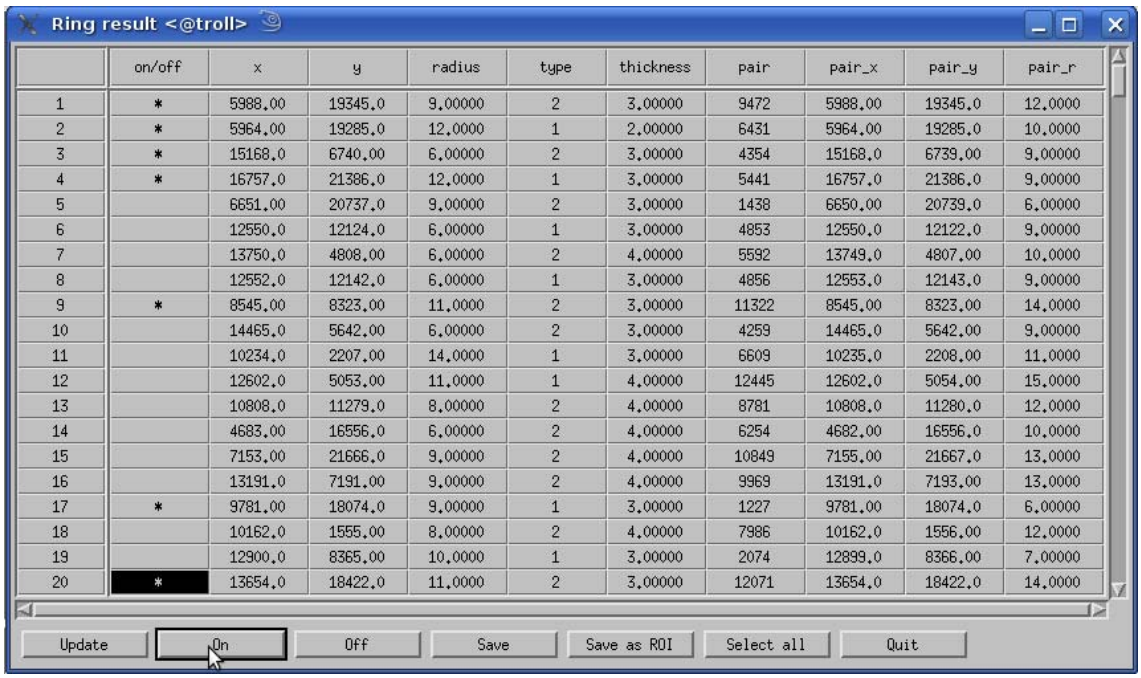
A validation process may be started in one of two ways.

1. It may be started directly after a ring search, by answering "yes" to the question if one wants to start validation.

2. It may be started from the CultSearcher main dialog (Figure 93).

In the latter case, CultSearcher will prompt the user for the result file of a previous ring search. The ring search output files end in "_rings.txt".

In both cases, a dialog listing all the ring detections and some attributes will appear (Figure 95). If CultSearcher is run in developer mode, then a dialog with more attributes will appear. The user may click on a line in the table, and the selected ring is displayed in the zoom window. There are buttons for switching rings on and off. By, for example, selecting ring detection number 20 in the list, the display(s) will zoom to that location in the image (Figure 96), and if the operator thinks this is a valid detection, then they can select the 'on' button (Figure 95).



	on/off	x	y	radius	type	thickness	pair	pair_x	pair_y	pair_r
1	*	5988.00	19345.0	9.00000	2	3.00000	9472	5988.00	19345.0	12.0000
2	*	5964.00	19285.0	12.0000	1	2.00000	6431	5964.00	19285.0	10.0000
3	*	15168.0	6740.00	6.00000	2	3.00000	4354	15168.0	6739.00	9.00000
4	*	16757.0	21386.0	12.0000	1	3.00000	5441	16757.0	21386.0	9.00000
5		6651.00	20737.0	9.00000	2	3.00000	1438	6650.00	20739.0	6.00000
6		12550.0	12124.0	6.00000	1	3.00000	4853	12550.0	12122.0	9.00000
7		13750.0	4808.00	6.00000	2	4.00000	5592	13749.0	4807.00	10.0000
8		12552.0	12142.0	6.00000	1	3.00000	4856	12553.0	12143.0	9.00000
9	*	8545.00	8323.00	11.0000	2	3.00000	11322	8545.00	8323.00	14.0000
10		14465.0	5642.00	6.00000	2	3.00000	4259	14465.0	5642.00	9.00000
11		10234.0	2207.00	14.0000	1	3.00000	6609	10235.0	2208.00	11.0000
12		12602.0	5053.00	11.0000	1	4.00000	12445	12602.0	5054.00	15.0000
13		10808.0	11279.0	8.00000	2	4.00000	8781	10808.0	11280.0	12.0000
14		4683.00	16556.0	6.00000	2	4.00000	6254	4682.00	16556.0	10.0000
15		7153.00	21666.0	9.00000	2	4.00000	10849	7155.00	21667.0	13.0000
16		13191.0	7191.00	9.00000	2	4.00000	9969	13191.0	7193.00	13.0000
17	*	9781.00	18074.0	9.00000	1	3.00000	1227	9781.00	18074.0	6.00000
18		10162.0	1555.00	8.00000	2	4.00000	7986	10162.0	1556.00	12.0000
19		12900.0	8365.00	10.0000	1	3.00000	2074	12899.0	8366.00	7.00000
20	*	13654.0	18422.0	11.0000	2	3.00000	12071	13654.0	18422.0	14.0000

Figure 95. The ring validation dialog.

When validating the rings, it is probably a good idea to view both the panchromatic image and a pansharpened multispectral image, and make them show the same portions by using the 'link displays' function. In Figure 96, the pansharpened image has the full color information from the multispectral acquisition, that is, 11 bits per color band. This allows for interactive contrast enhancement by using the enhance menu in the image display window. The enhance option 'scroll linear 2%' was used in Figure 96 for the pansharpened image.

The 'update' button (Figure 95) needs special mention. All ring edge detections are drawn as circles. Unfortunately, the drawing of circles is very slow in ENVI, so one should limit redrawing of rings to a minimum. So, when switching rings on and off, the drawn circles are not updated accordingly until the 'update' button is clicked.

The user may save a partial validation result and continue a later time. However, rings that have been marked "off" are not saved. So, it is a good idea to always save with a different file name.

Figure 96. Ring detection number 20 in the list (Figure 95).

6.2 Further possible improvements

The archaeologists should report back to NR suggestions for user interface improvements. We have identified the following possible user interface improvements.

1. The ring validation dialog (Figure 95) could have a column with confidence values (e.g., -1, 0, .. 9) instead of the on/off column. '-1' would mean a certain false detection, '0' would mean a very doubtful detection, 1 would mean an uncertain detection, and so on, so that '9' means a very certain detection. When saving the ring validation file, only the ring detections with a negative confidence value should be discarded.

7 Tutorial: Geocorrection of Quickbird images using ENVI

In 2008 we experienced difficulties regarding agricultural masks not agreeing well with the satellite images. The images were acquired at off nadir incidence angles, resulting in horizontal shifts which depended on the elevation above sea level in each point on the ground.

To compensate for this, we need to perform a geometrical correction, using an elevation model and ground control point. The satellite image contains parameters that can be used together with an elevation model to do an orthorectification. However, the parameters are only approximate, and ground control points are needed for better accuracy. Shape files with outlines of agricultural areas, road and building outlines, an/or lake and river outlines can be used for this purpose.

The geometric correction is done using ENVI functions available from the ENVI main menu.

7.1 Preparations

Step 1: Start ENVI.

Start ENVI, or, alternatively, CultSearcher. From the ENVI main menu, you should be able to locate the function “Orthorectify Quickbird with ground control” (Figure 97).

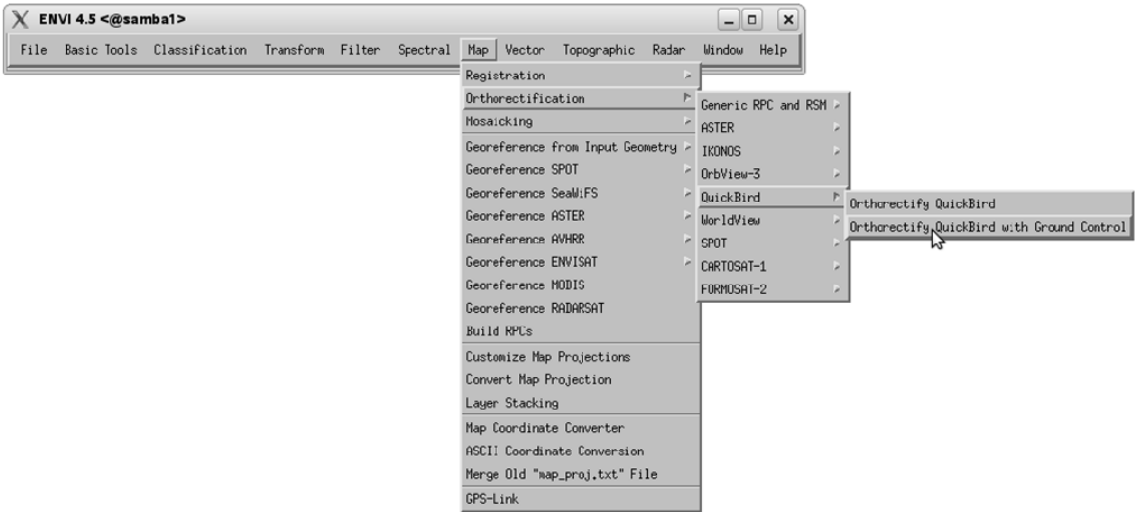


Figure 97. Location of the function "orthorectify Quickbird with ground control" in the Envi menu system.

However, if you start this function now, you will get a warning (Figure 98).

Figure 98. Warning produced by Envi if you try to start orthorectification with no image display.

Instead, you should open the original image, and, for example, the agricultural mask image (Figure 99).

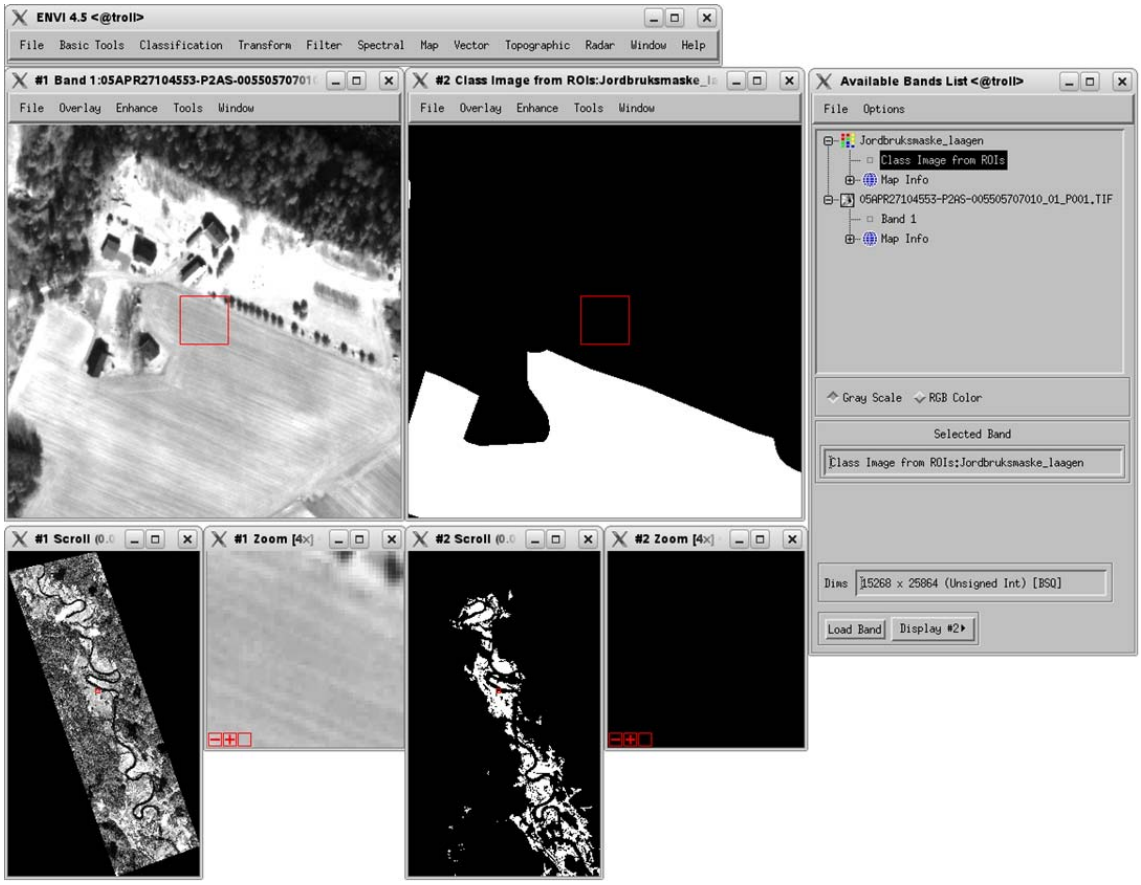


Figure 99. Two displays are needed for orthorectification with ground control points.

Then, we need to open some vector layers, which will be used for ground control points. Select the function “open vector file” (Figure 100).

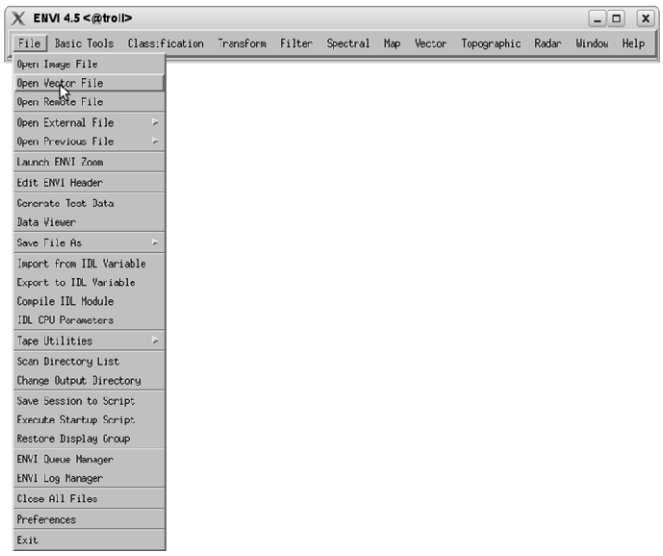


Figure 100. The function "open vector file" is located in the "file" menu.

The select vector filename dialog appears (Figure 101).

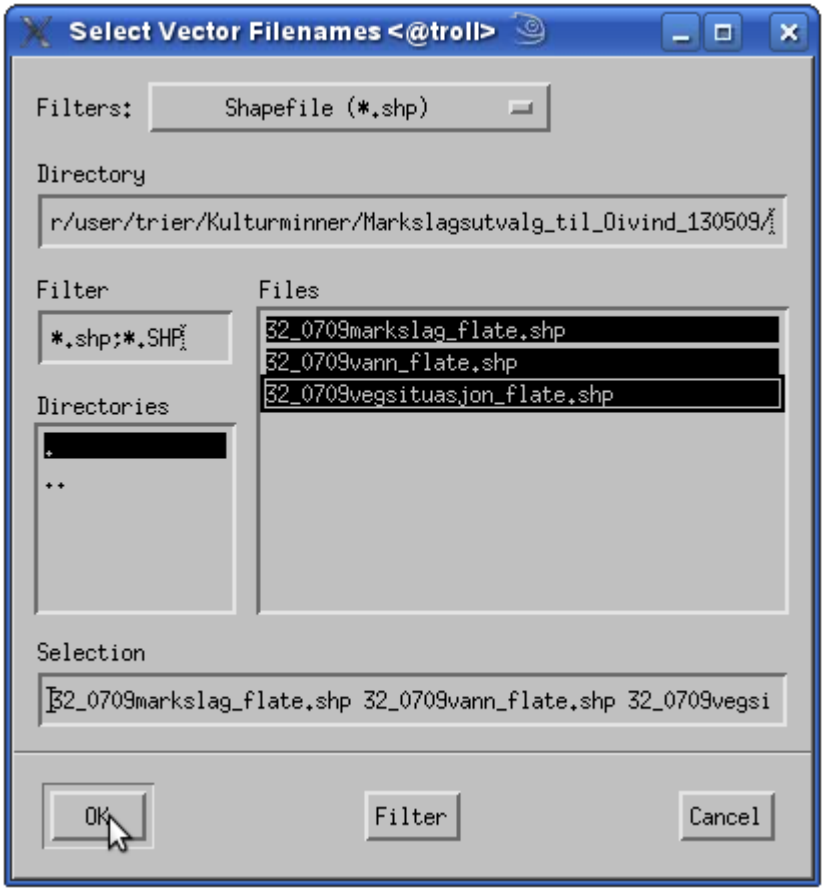


Figure 101. Dialog for selecting a vector file.

Select shapefile as filters. Select all the relevant shape files, and press OK. All the shape files need to reside in the same directory.

The next dialog is used to set the appropriate map projection. This is the map projection of the input vector files, and will also be the map projection of the output geo-corrected raster file.

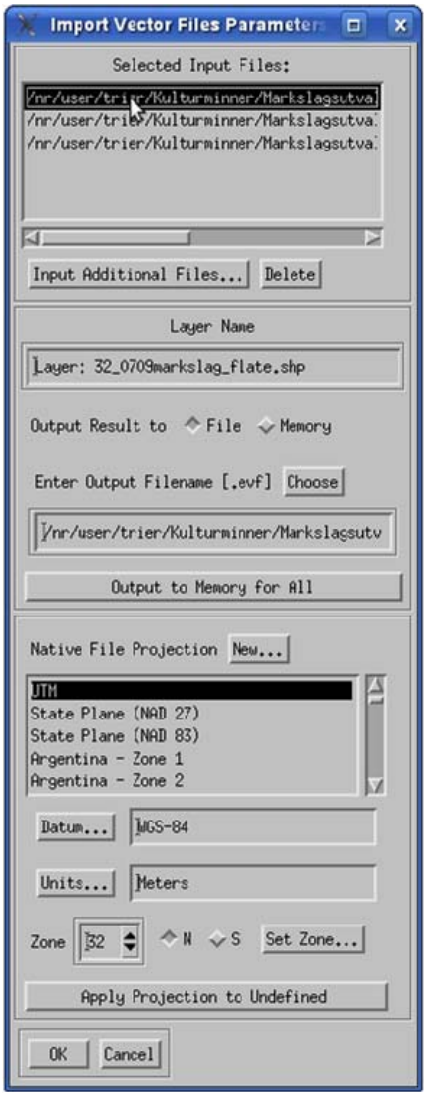


Figure 102. Dialog for setting map projection parameters.

In the bottom half of the dialog, we will select UTM, WGS-84 as datum, and the appropriate zone, e.g., 32. It might happen that the evf files exist already (Figure 103). This is OK, just choose to overwrite.

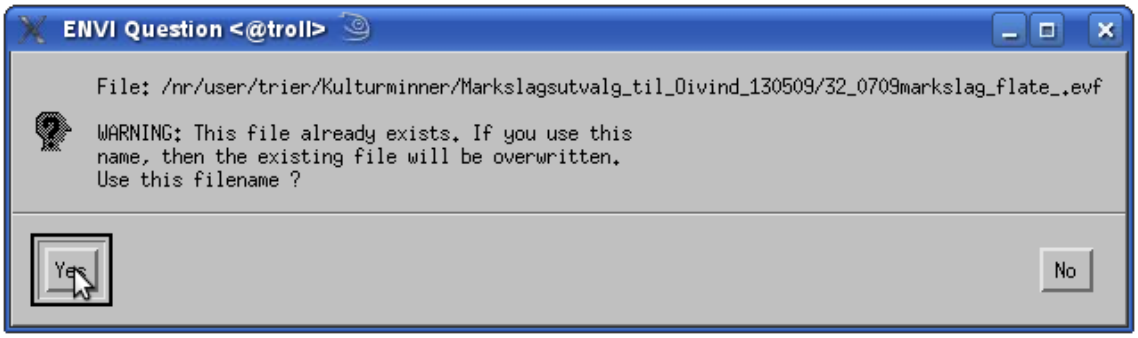


Figure 103. Dialog that warns if evf files exist already.

In any event, the next dialog (Figure 104) will ask you to select vector layers.

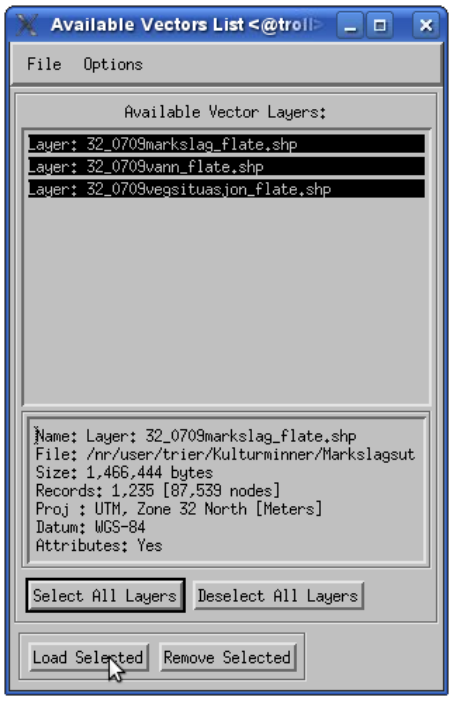


Figure 104. Dialog for selecting which vector layers to display.

Select all layers, and click on "load selected". Now a small dialog appears (Figure 105), asking which window should be used for the vectors.

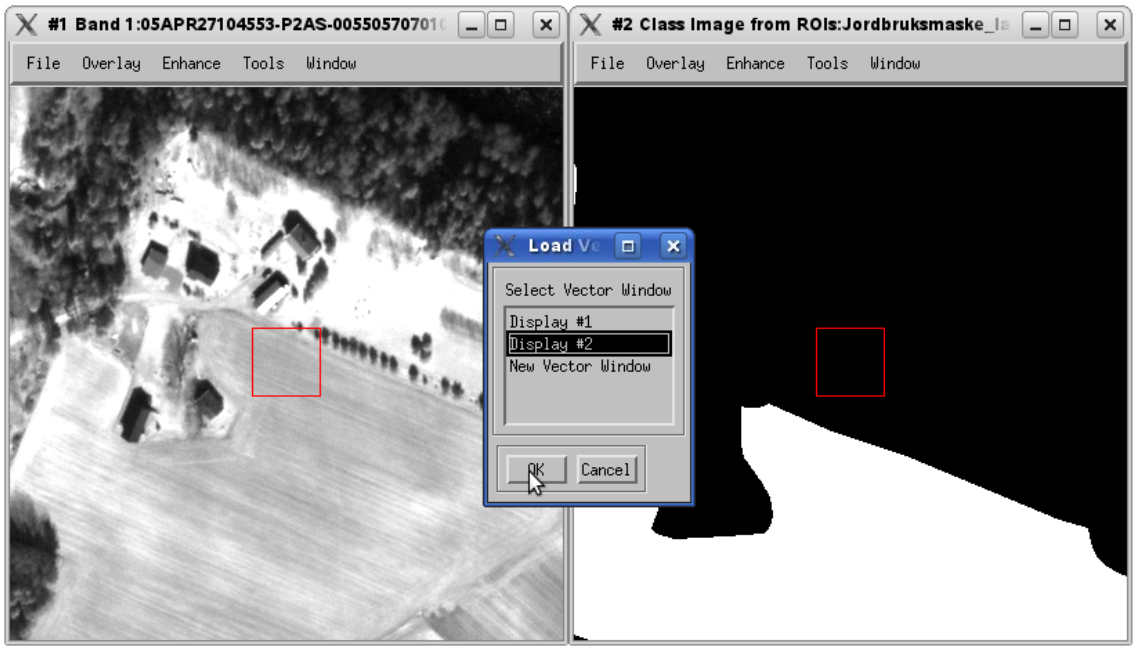


Figure 105. The small dialog is used to select the display containing the vector layers.

Select the display that is ***not*** the original image. In Figure 105, we would select the image with the agricultural masks, that is, display 2.

You may want to change the colors of some of the vector layers, to make them more intuitive. In the display with the vector layers, right-click with the mouse, and in the pop-up menu (Figure 106), select “edit layer properties…”

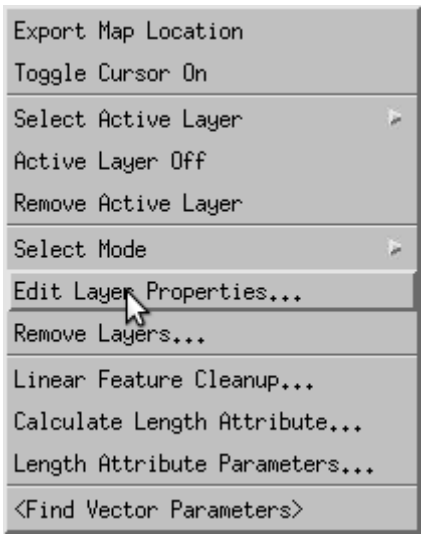


Figure 106. Pop-up menu.

In the dialog that appears (Figure 107), you can select a layer and change its color.

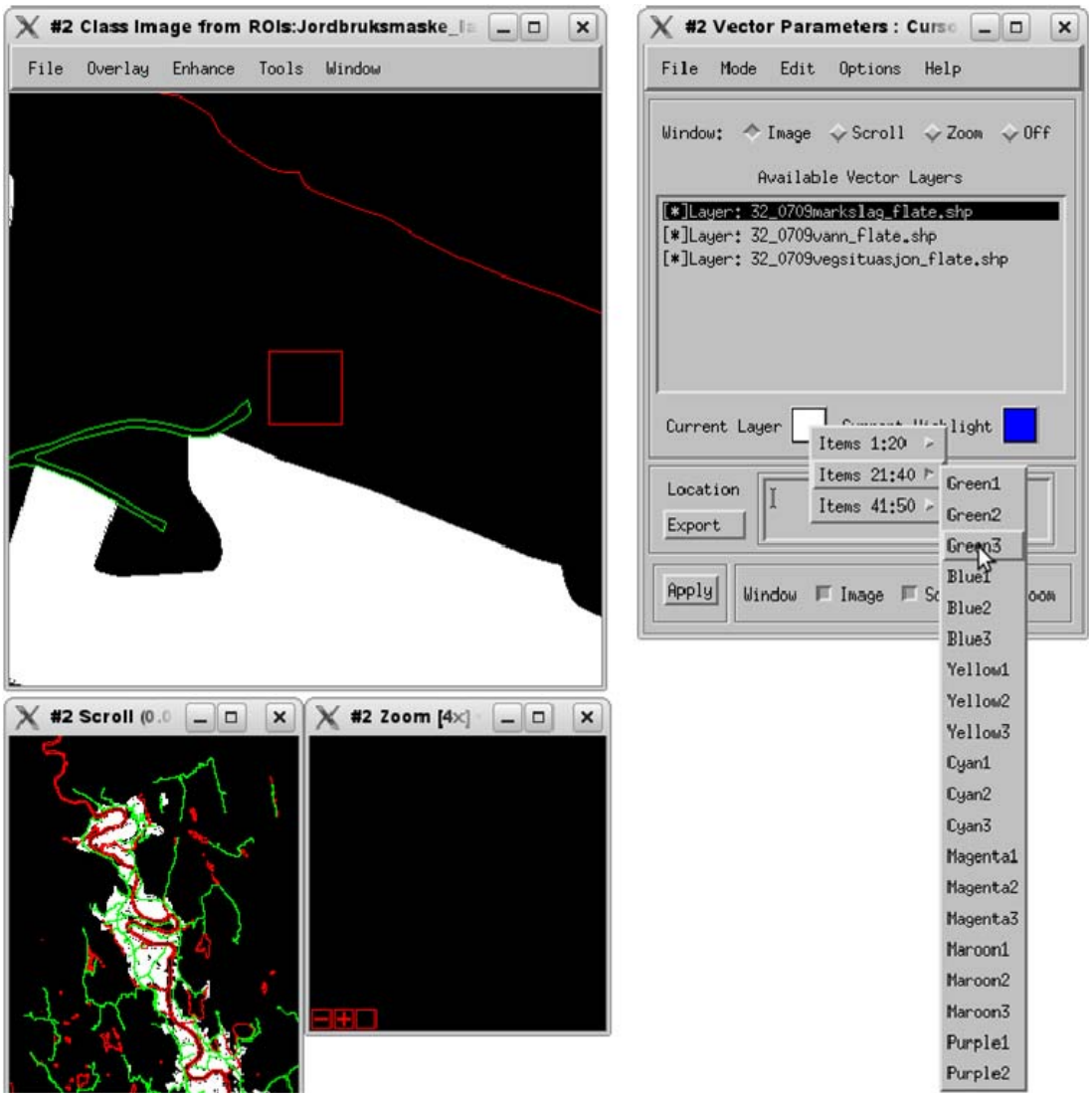


Figure 107. The vector parameters dialog allows the user to change colors is activated by right-clicking the coloured square next to "current layer".

You can ignore the “current highlight” color.

For example, you can use green for agriculture (markslag), blue for water (vann), and brown for roads (veg) (Figure 108).

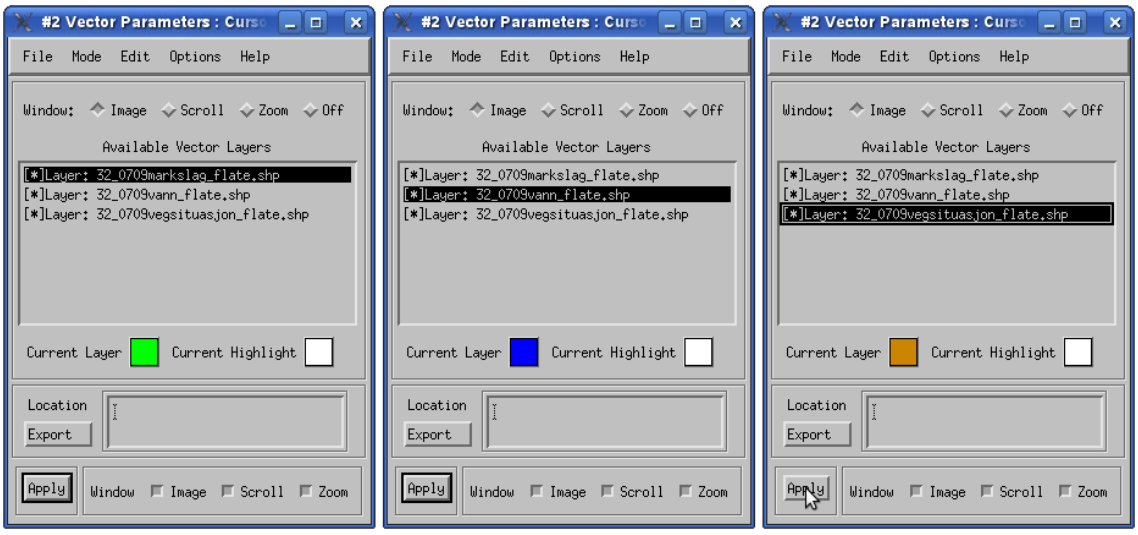


Figure 108. Possible colors for the vector layers.

When all the colors are selected, we update the display by clicking “apply”. We can minimize the dialog, but it is not necessary to close it.

The display with the vector layers should now have the vectors drawn in more intuitive colors (Figure 109).

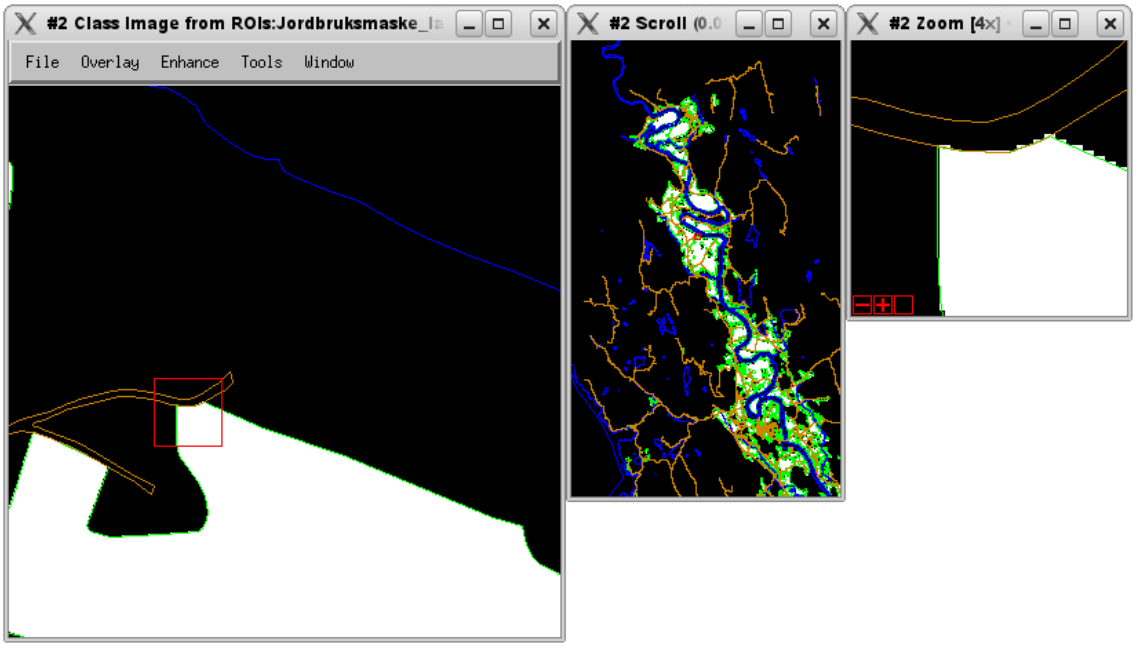


Figure 109. The vector layers now appears with the colors that were chosen in Figure 108.

Now that we have one display with the original image, and one display with vector layers, we can start the orthorectification function. Select the function “orthorectify Quickbird with ground control” (Figure 110).

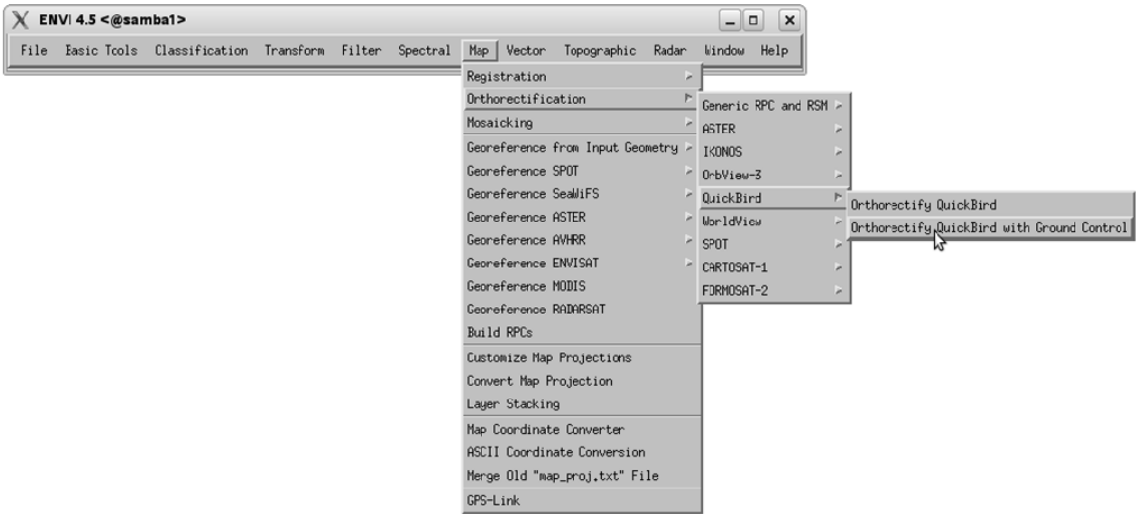


Figure 110. The orthorectification function's location in the meny hierachy.

We must select the display with the original image as the input display (Figure 111). A copy of this image will be transformed and saved to a new filename.

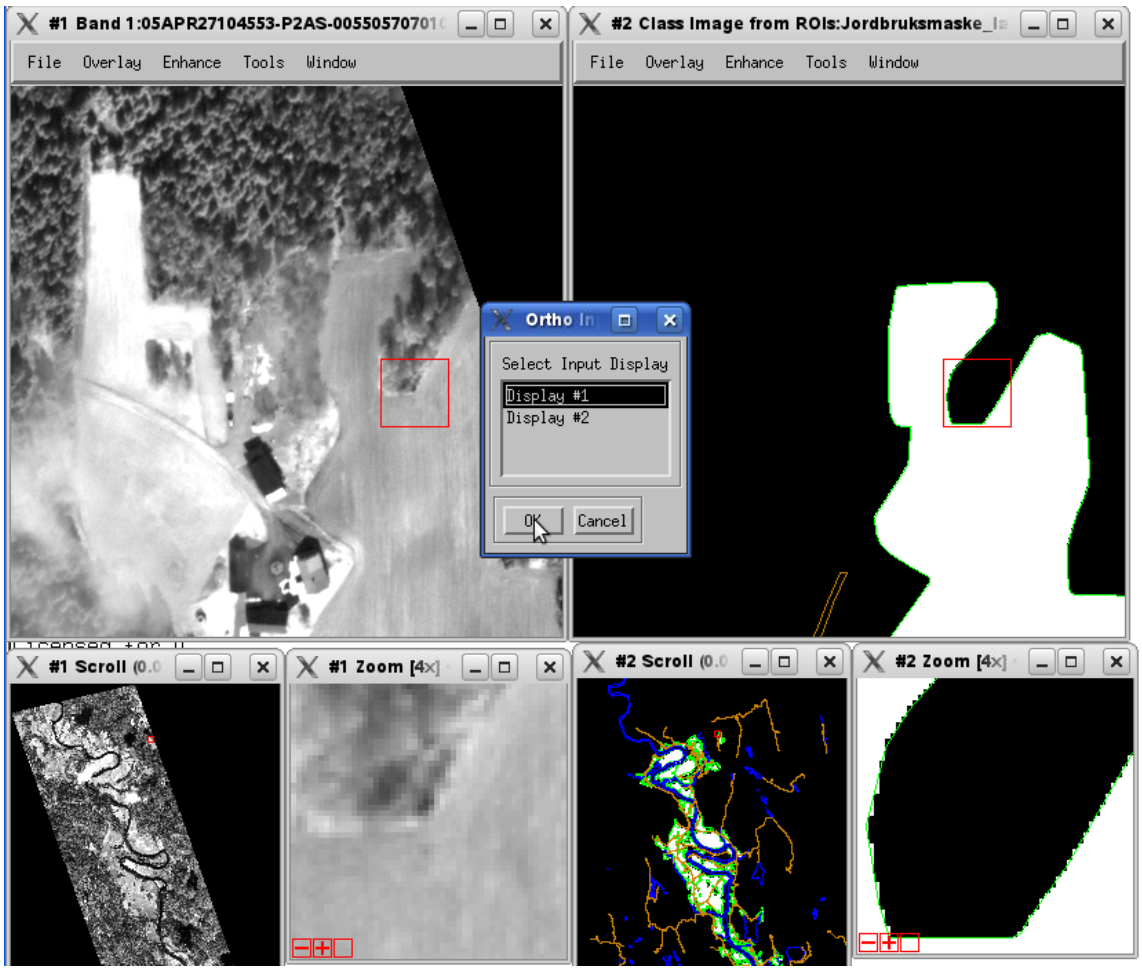


Figure 111. The orthorectification procedure promts for the display which has the original image.

7.2 Registration of points

Then we need to locate corresponding points which can be accurately defined in both displays. It is a good idea to link displays when looking for points. You link displays by right-clicking with the mouse in one of the displays, and selecting “link displays”. Then a dialog appears.

[Insert dialog for link displays]

[Describe how to link displays]

In Figure 112, a suitable point has been found, which can be quite accurately located in both images.

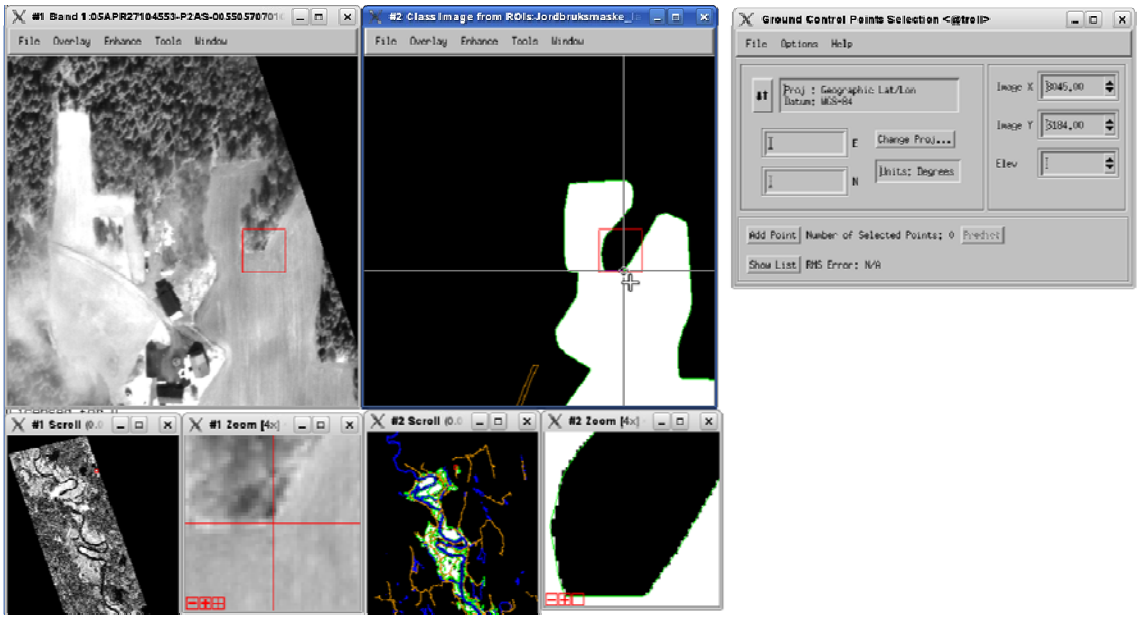


Figure 112. Simultaneous location of ground control point in original image and vector layers.

In the original image, move the cross in the zoom window by using the arrow keys. In the vector layers, the cross hair cursor will snap to the “current” vector layer. See further below for a description of how to switch the current vector layer. When the point has been accurately located in both displays, right-click with the mouse and select “export map location” in the popup menu (Figure 113).

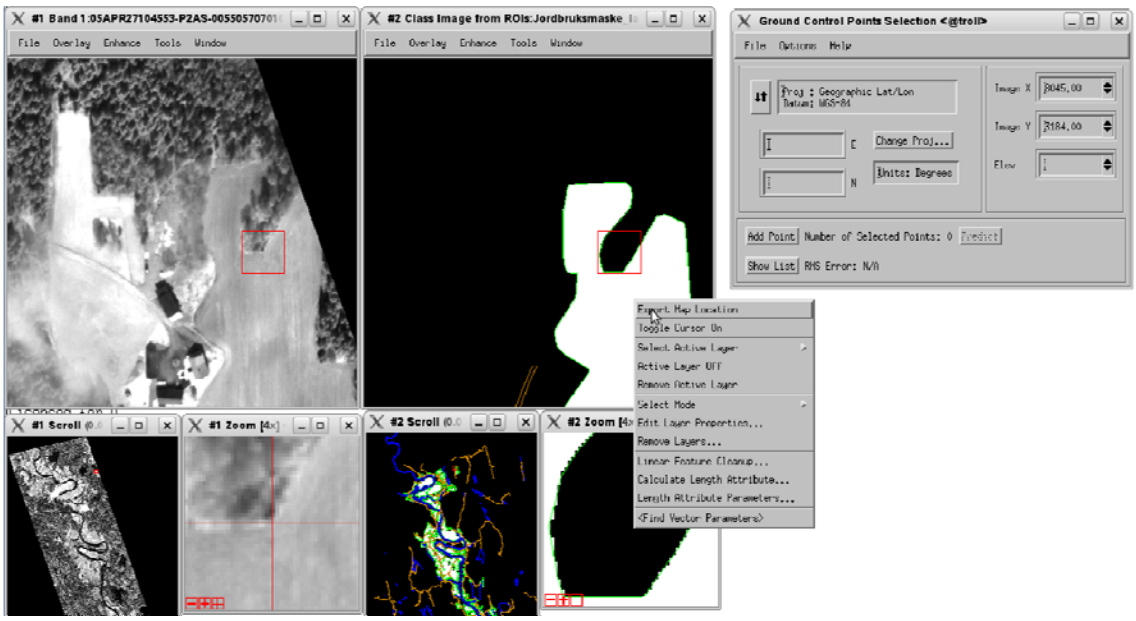


Figure 113. The popup menu has a function named 'export map location'.

The map coordinates are copied to the “ground control points selection” dialog (Figure 114).

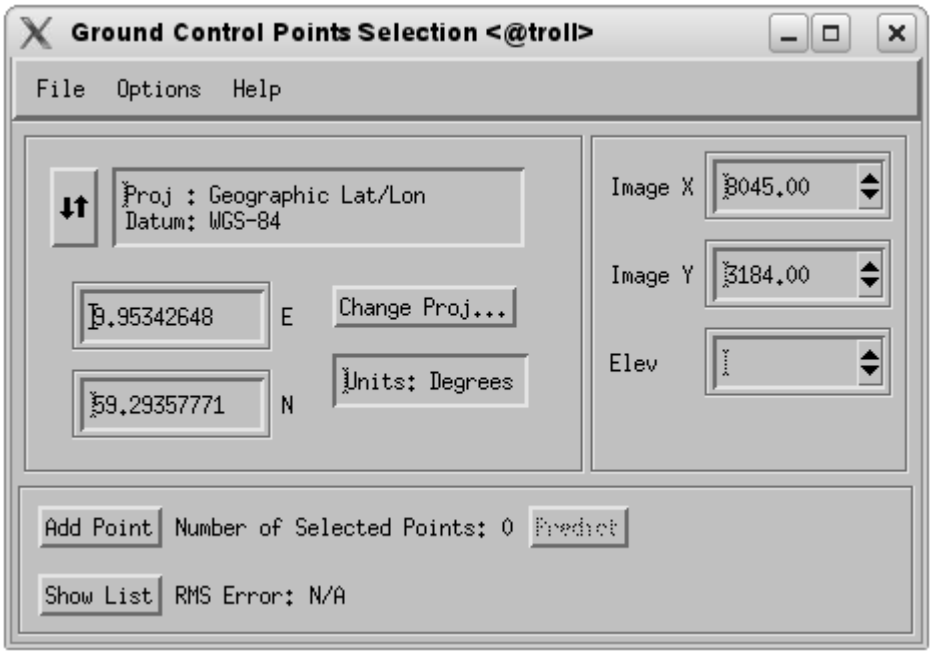


Figure 114. The ground control point selection dialog.

However, the elevation is missing, and must be determined. One possible source for this information is http://kart.statkart.no (Figure 115). Note that the contour line interval is 5 m in some parts of the map, and 10 m in other parts of the map.

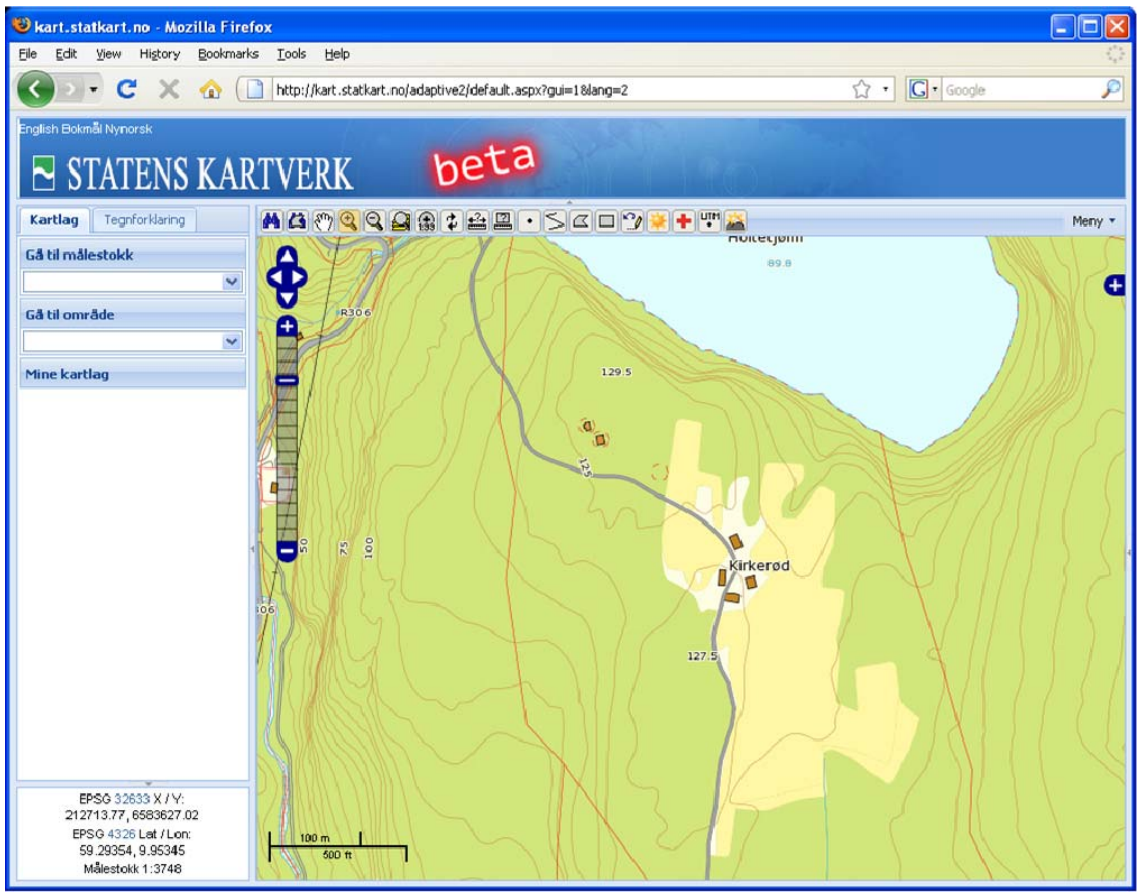


Figure 115. Elevation values may be found in http://kart.statkart.no

Or you may have an in-house access to a digital map containing elevation values. In any case., enter the elevation value in the dialog, and click on “add point” ().

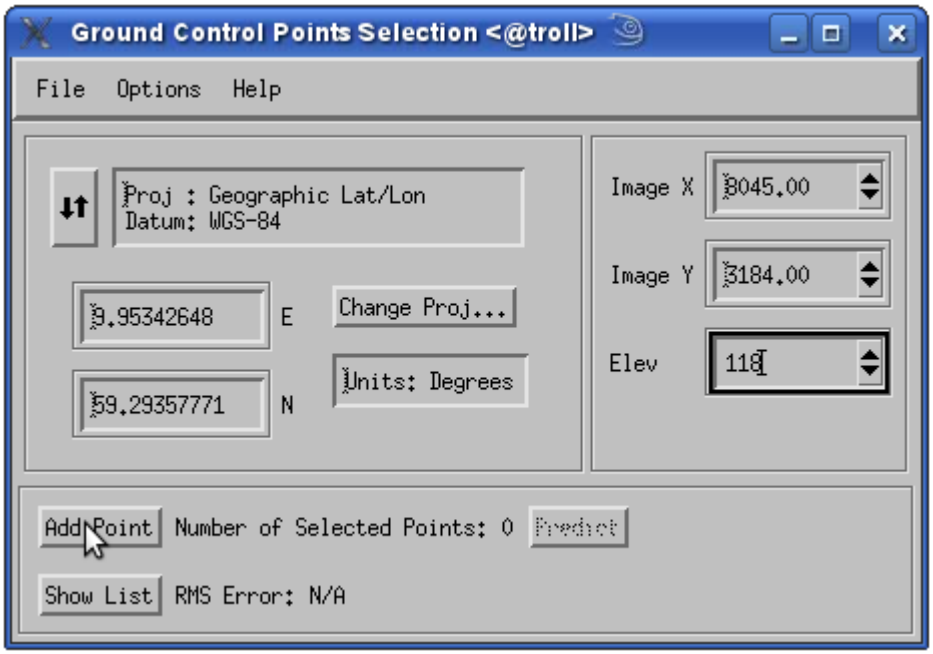


Figure 116. When the elevation value has been entered or updated, one may click 'add point'.

To see that the point has been collected, select “show list” ().

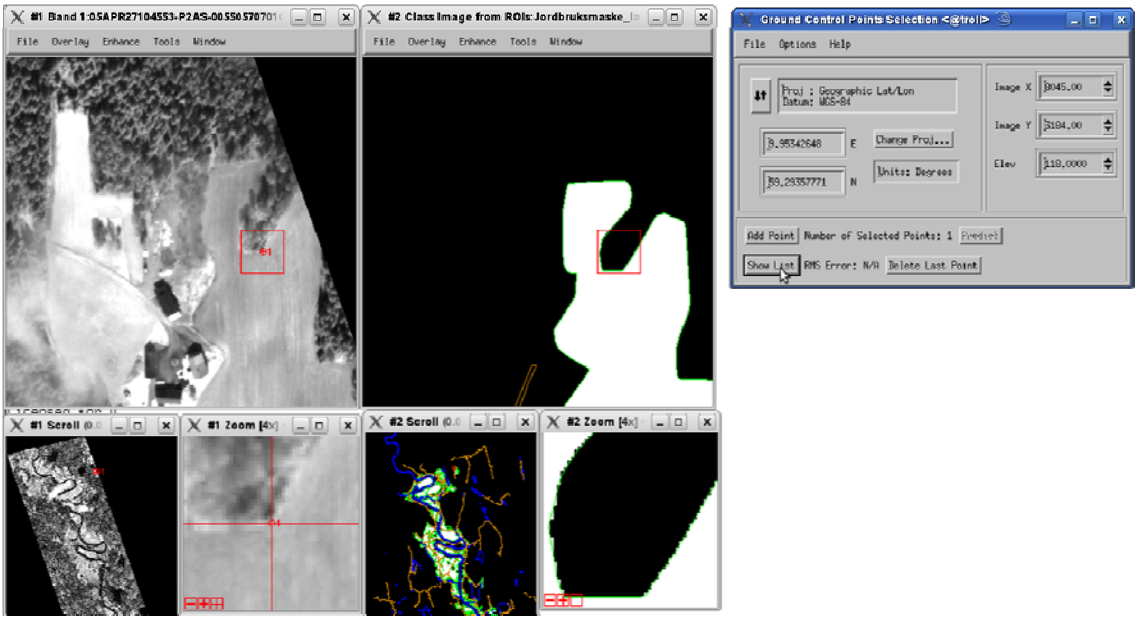


Figure 117. The new ground control point is marked in the original image. To see a list of all ground control points so far, click on 'show list' .

The orthorectification ground control points list now contains the first point (Figure 118).

Figure 118. The ground control points list.

7.3 Change of active vector layer

It my happen that we need to snap to another vector layer that the one which is currently active. Right-click with the mouse in the display containing the vector layers, and select “select active layer” in the popup menu, then select the new active layer (Figure 119).

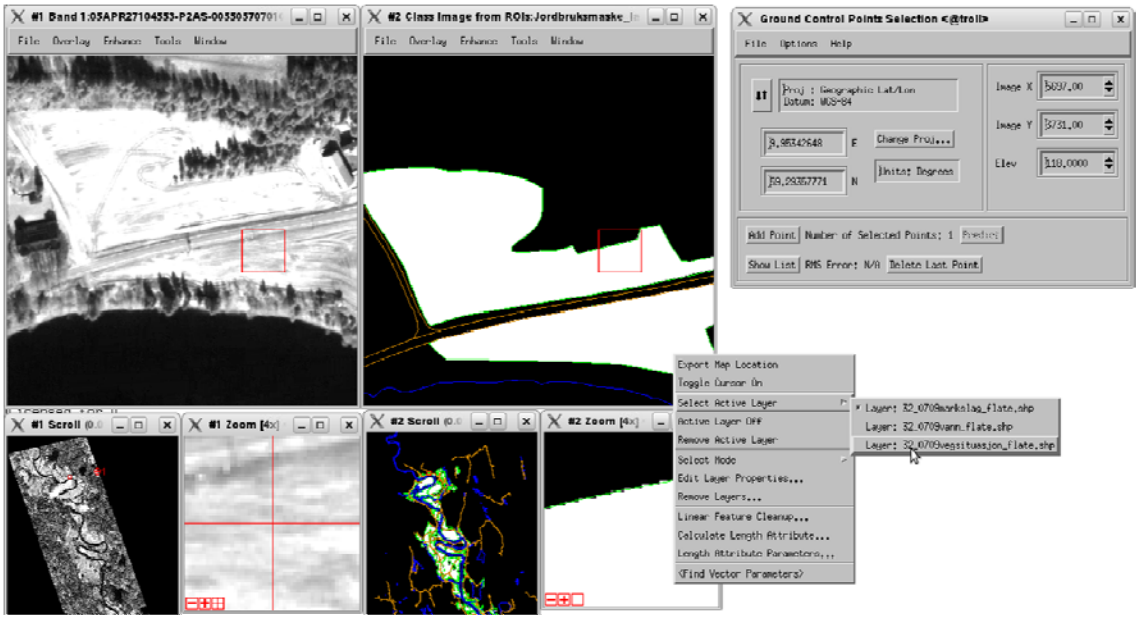


Figure 119. From the popup menu one may change active vector layer.

Now, we can proceed as before, by accurately locating a point in the original image, using the arrow keys, and accurately locating the corresponding point in the vector display, followed by “export map location”. As mentioned earlier, this function is in the popup menu that we obtain by right clicking in the vector display ().

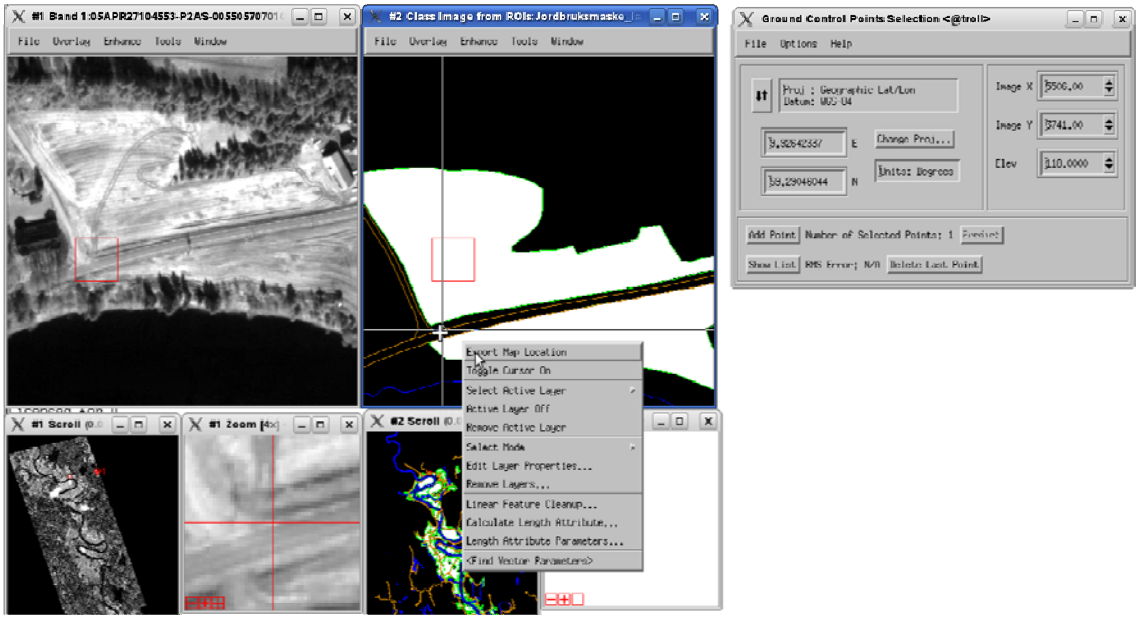


Figure 120. By selecting 'export map location', the new location is copied to the ground control points selection dialog

Then, we need to update the height (Figure 121). If we forget this step, the previous height is used, which may be completely wrong.

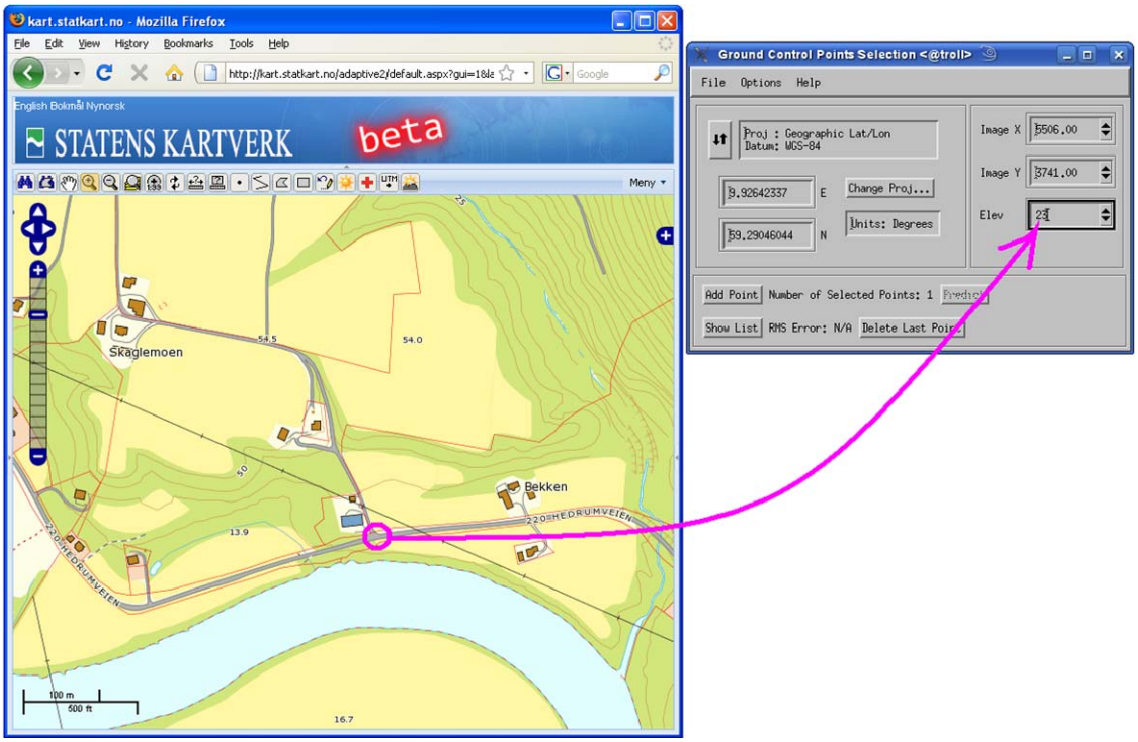


Figure 121. Remember to update the height!

In the example image, 14 ground control points have been recorded (Figure 122).

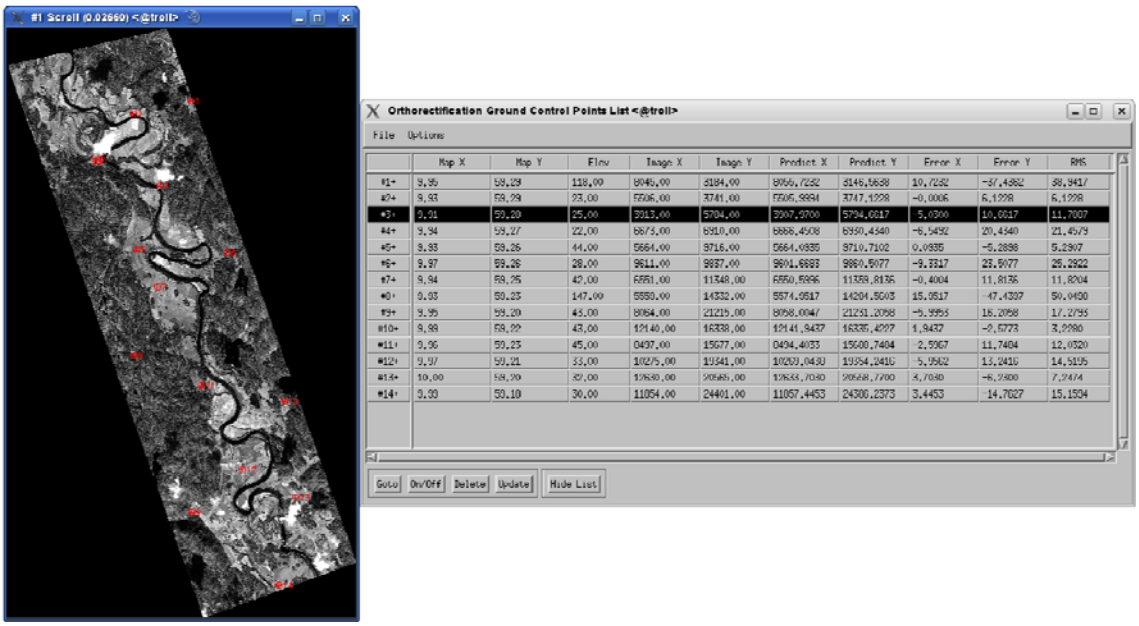


Figure 122. For the Lågendalen image, 14 ground control points have been collected.

The ground control points must be stored in a file. Select the function “save GCPs with map coordinates” (Figure 123).

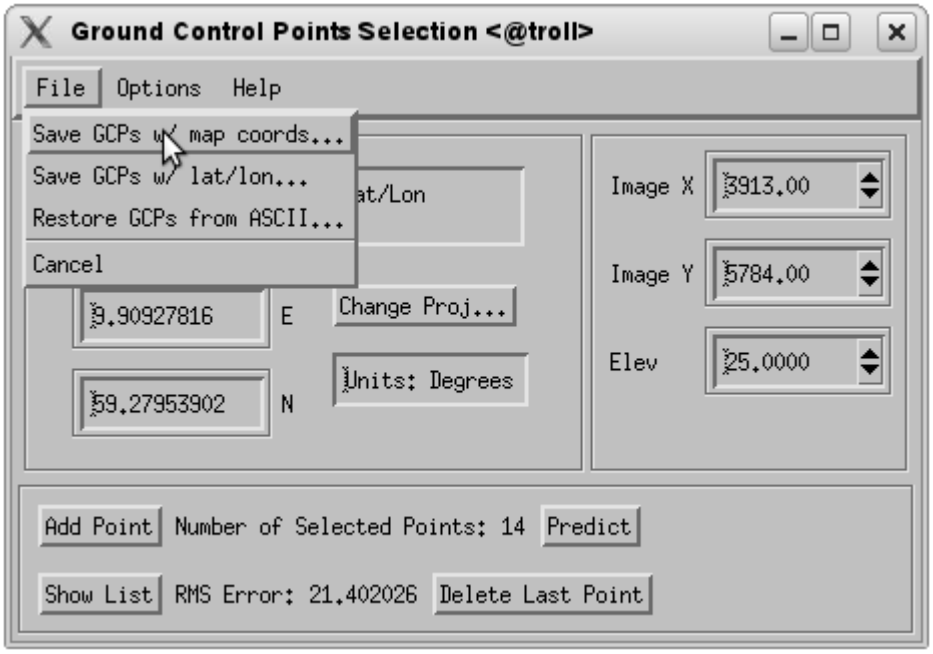


Figure 123. The function to save the ground control points is located in the file menu of the ground point aelection dialog.

Next, we can start the actual orthorectification of the input image, by selecting the function “orthorectify file…” (Figure 124).

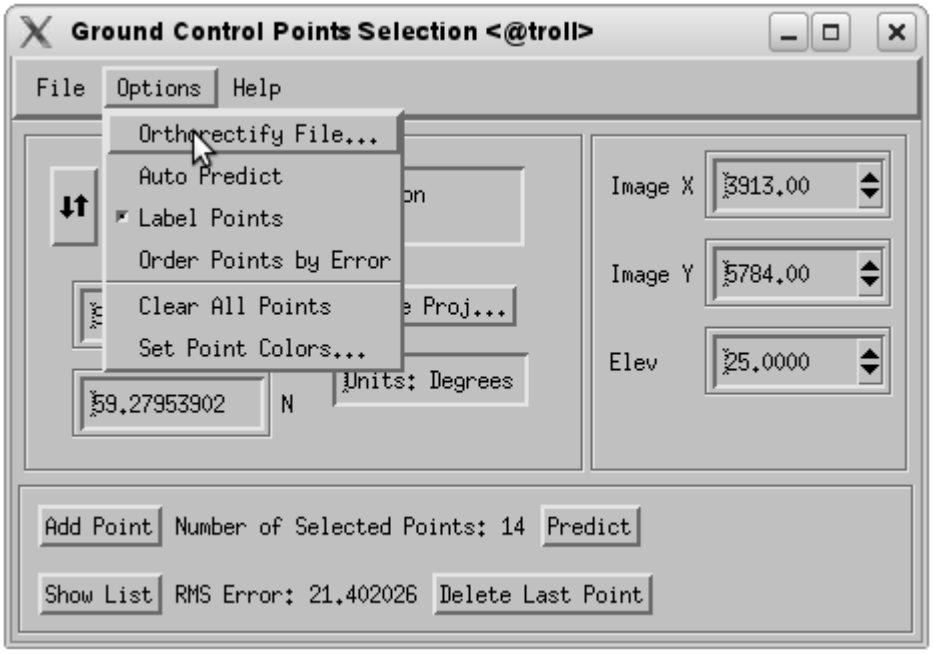


Figure 124. The function to start the orthorectification process is located in the 'options' menu.

We first select the original image (Figure 125).

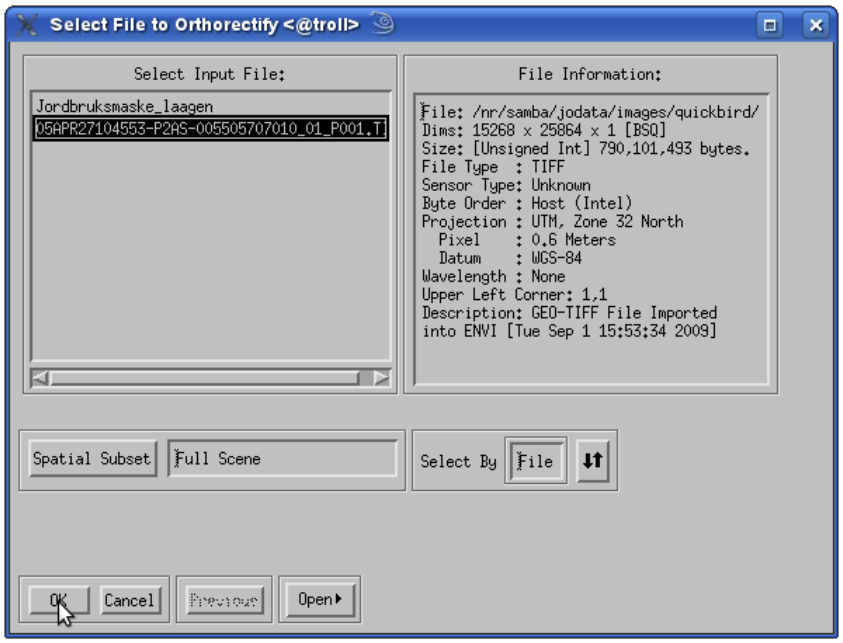


Figure 125. Selection of image to orthorectify.

Next, we need to specify several parameters (Figure 126).

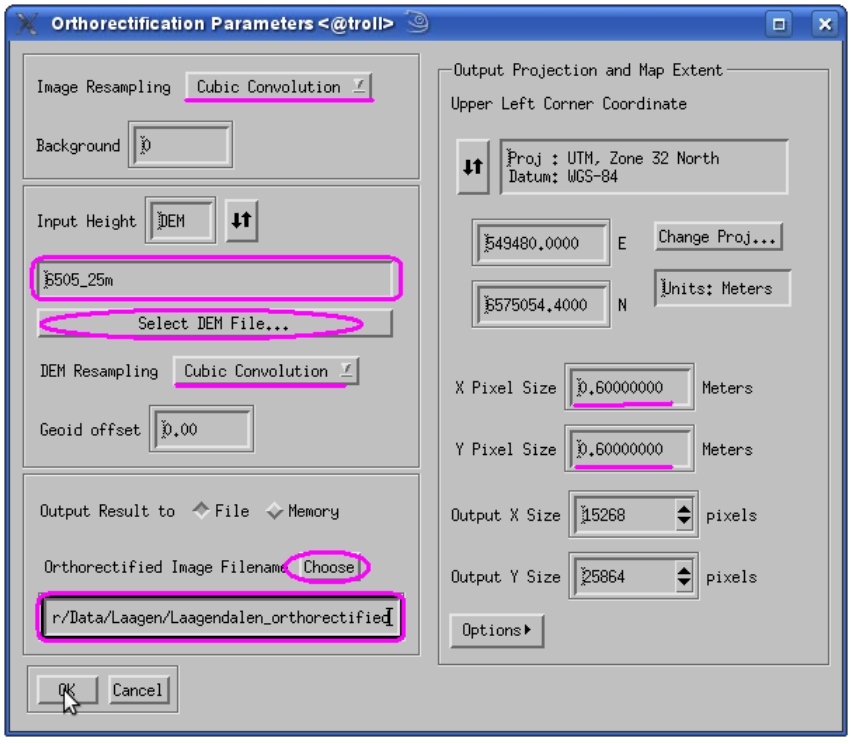


Figure 126. Orthorectification parameters.

For image resampling, select “cubic convolution”. For input height , select DEM, and select the appropriate DEM file. Specify the name of the output file. Verify that the output projection is correct. Make sure the x pixel size and y pixel size values are correct. For Quickbird

panchromatic and pansharpened images, it should be 0.6 m in both directions. Also verify that the output x and y sizes are plausible, that is, they should be approximately the same as for the input image. Click OK to start processing

The processing takes a little while. First the DEM is resampled, then the input image is orthorectified to produce the output image (Figure 127).

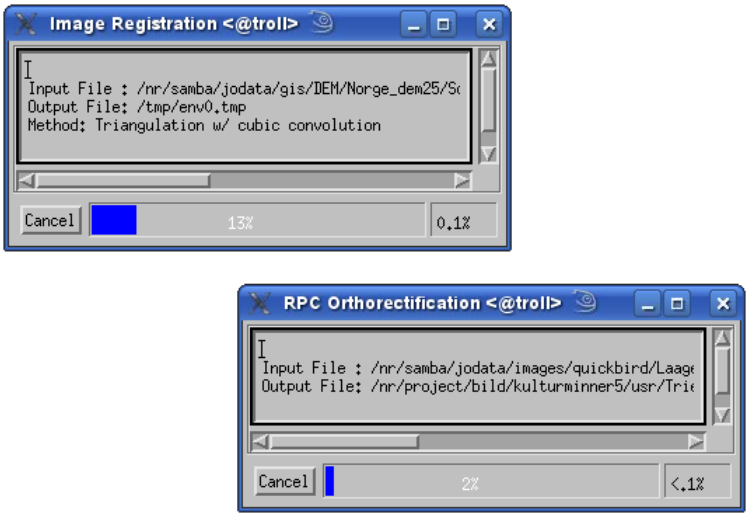


Figure 127. Progress dialoges during the orthorectification processing.

When the processing has finished, we can open it and compare it with the vector layers.

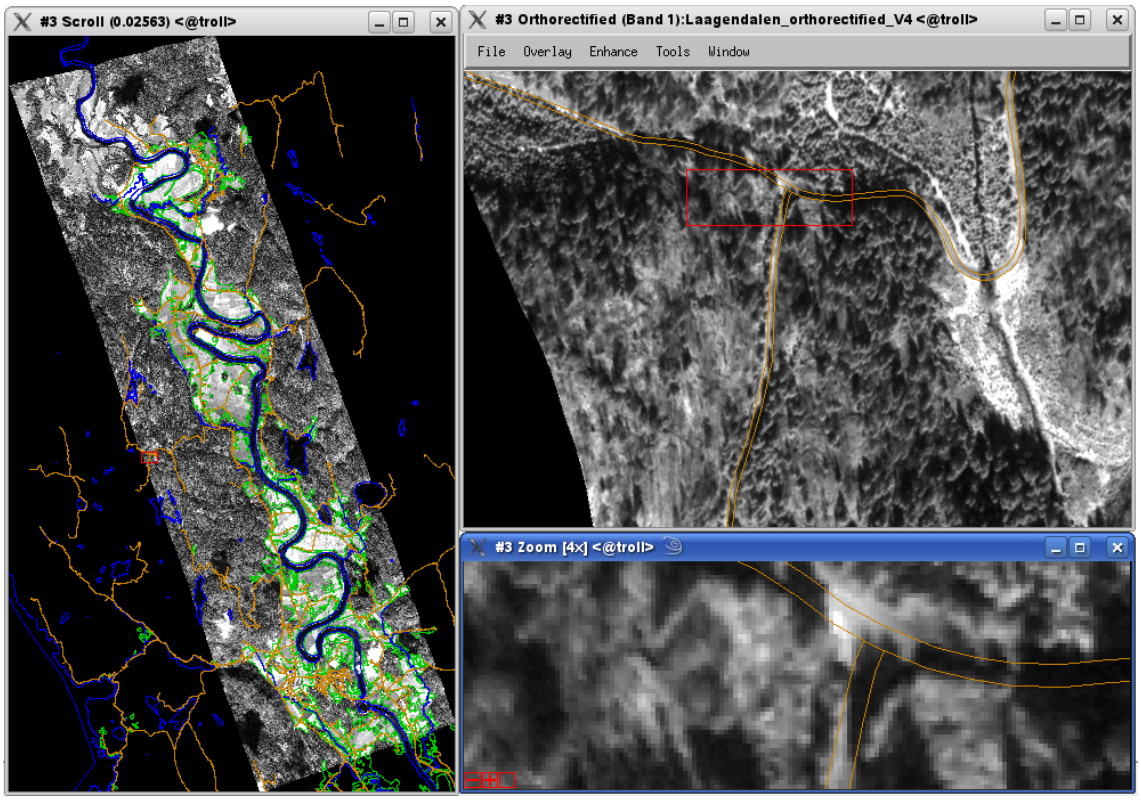


Figure 128. The orthorectified image with vector layers on top. The vectors can be loaded from the 'available vectors list' dialog (see Figure 104 and description on page 119).

We can check that road intersections match. More importantly, we can check if agricultural borders match (Figure 129-Figure 130).

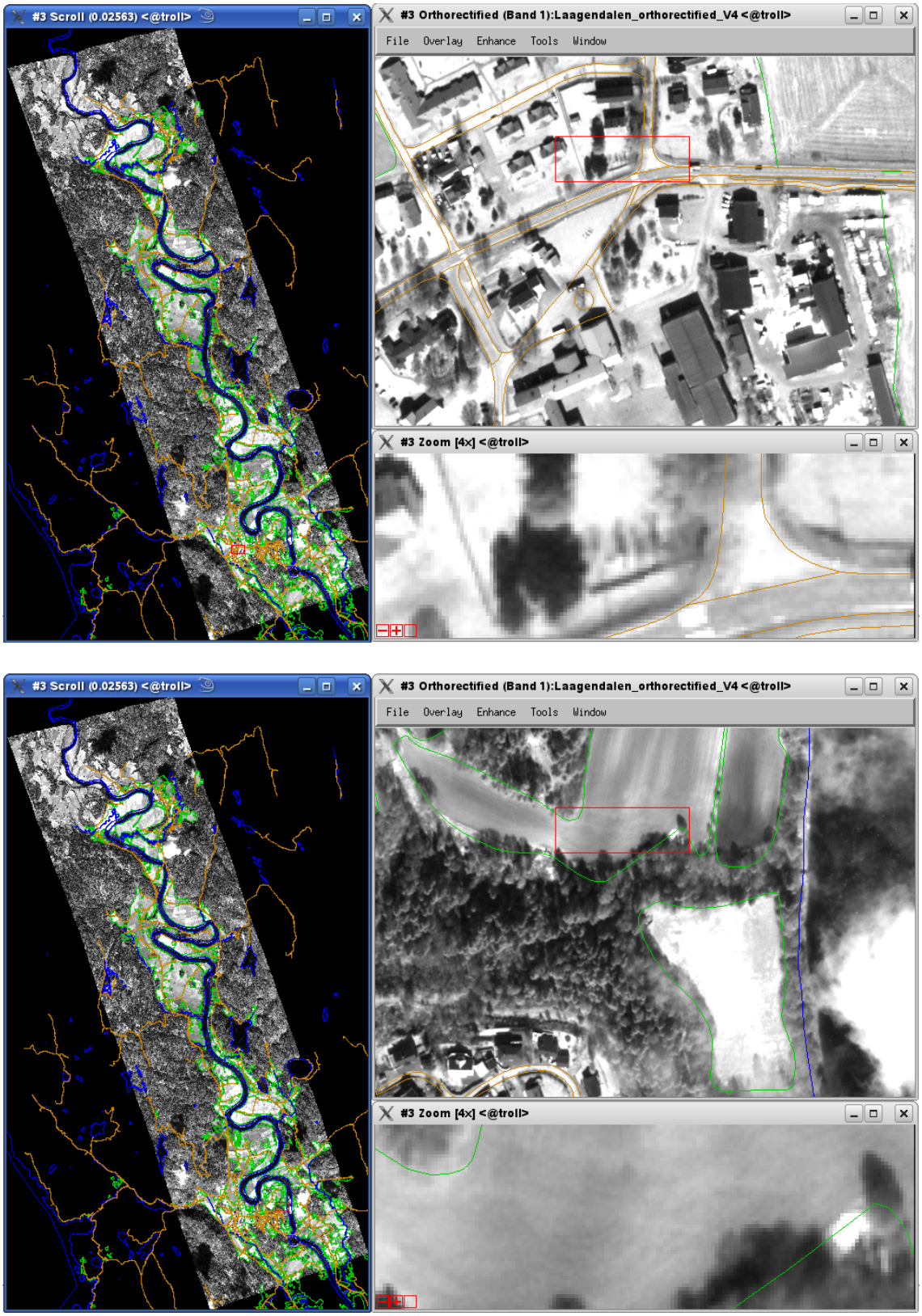


Figure 129. Top: verification of road intersections. Bottom: verification of agricultural borders.

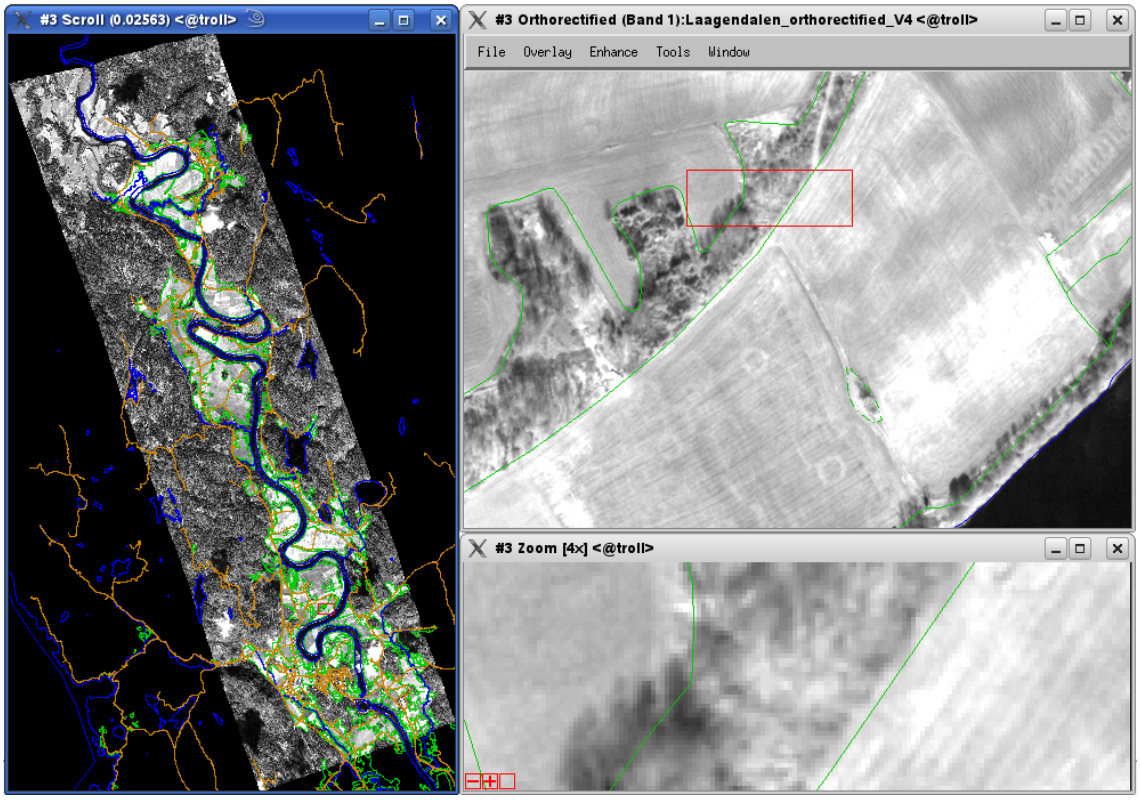


Figure 130. Verification of agricultural borders.

8 Concluding remarks

2009 has been a break through year in the project, by demonstrating that previously unknown cultural heritage sites can indeed be detected by satellite remote sensing algorithms in a cost-effective manner. The new detections were made on newly acquired Quickbird images as well as archive Quickbird images. It is important to keep in mind that none of these images had been used to train the detection algorithm. The training images included a spring image from late April and a summer image in late July, both images with near ideal imaging conditions with very few clouds. The two new images acquired in July 2009 had a lot of clouds, cloud shadows and haze. The local contrast enhancement method was able to remove the effects of cloud shadows and haze.

The number of previously unknown cultural heritage sites that were detected by CultSearcher varied from image to image. One explanatory factor is the acquisition date relative to the growing season of cereals. The Tønsberg and Tjølling images were acquired only one week apart, still the detection results were dramatically different. Another explanation is that the training data set was very limited, so by including more training data, better recognition performance could be expected.

A number of possible further improvements of the CultSearcher software have been identified.

1. The memory requirements should be reduced when processing large images. For example, the Tjølling image from 2009 required more than 20 gigabyte of memory, and the Tønsberg image even more. It is possible to process these images on Linux computers with 64 gigabyte memory. However, the users can not be expected to have this amount of memory. A solution is to let CultSearcher subdivide large images into smaller, overlapping subimages, process each part and combine the results. The processing result can then be verified using the entire image.

2. The processing time for large images was very long. Most of the time was spent on feature extraction. One could look into ways to improve the speed of computing features.

3. More data is needed for validation. A few new images were acquired in 2009, and we plan to acquire more images in 2010.

4. One could look into better ways of sorting the detected rings. Although the present sort order is somewhat meaningful, it is still so that false detections are mixed in with the true detections.

5. Fields with stripes cause many false detections, and a method to mask these automatically could be considered.

6. The possibility of processing aerial images, in the form of orthophotos, should be considered.

7. The project could be extended to include more counties in Norway.

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