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Note

Application of remote sensing in cultural heritage management

CultSearcher project report 2015

Note no. SAMBA/08/16

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Date 1 March 2016

RIKSANTIKVAREN

UiO : Kulturhistorisk museum

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Title	**Application of remote sensing in cultural heritage management**
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Quality assurance	Øivind Due Trier
Date	1 March 2016
Year	2016
Publication number	SAMBA/08/16

Abstract

This 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 project focuses on the development of automated pattern recognition methods for detecting and locating cultural heritage sites. This note describes the achievements of the project during 1 March 2015 – 1 March 2016. The project is funded by the Norwegian Directorate for Cultural Heritage (Riksantikvaren).

The project has seen two major breakthroughs in the current reporting period. Firstly, the use of deep-learning methodology is able to dramatically improve the detection performance of semi-automatic detection of charcoal kilns. An initial experiment indicates that 85% of the true charcoal kilns may be detected, with only 10% false positives. A similar approach may be used in semi-automatic detection of grave mounds. Secondly, the pilot portal has been scaled to be able to process entire airborne laser scanning datasets. The previous version was only able to process small test data sets of less than a few km². However, the new detection methods, based on deep learning, are not available from the pilot portal yet.

A third major activity has been field verification of semi-automatic detections. The main focus has been on charcoal kilns belonging to the ironwork in Lesja, Oppland County, resulting in a near complete mapping of the kilns and producing valuable cultural-historical information.

Preliminary results from the development of the pilot portal and the use of deep learning for the detection of charcoal kilns will be presented at international conferences in March and April 2016.

In conclusion, the project has now scientifically demonstrated that semi-automatic detection methods work when applied to airborne laser scanning (ALS) data. This is of great importance now that large amounts of ALS data are becoming available to heritage management because of the implementation of the National Detailed Height-model in Norway. Project funding for one more year is vital to implement deep learning-based methods in the pilot portal. This will turn the pilot portal into a workhorse for semi-automatic detection of archaeological structures from airborne laser scanning data, of great benefit for the archaeological use of ALS data.

Keywords	Airborne laser scanning, lidar, grave mounds, charcoal kilns, iron works, pitfall traps, hunting systems, deep learning
Target group	Archaeologists, remote sensing researchers
Availability	Open
Project number	220 741

Research field	Archaeology, remote sensing, machine learning
Number of pages	195
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1 Introduction

Several Norwegian municipalities are experiencing growing pressure on agricultural and forested land for development, being it new residential areas, new mountain cabins and hotels, new highways, or other purposes. The traditional mapping of cultural heritage, mainly based on chance discovery and with inaccurate positioning, has proven inadequate for land use planning. Therefore, the Norwegian Directorate for Cultural Heritage, in cooperation with some Norwegian counties and municipalities, are investing in the development of new methods, using new technology, for a more systematic mapping of cultural heritage.

A project was started in 2002 by the Norwegian Directorate for Cultural Heritage, aiming at developing cost-effective methods for surveying and monitoring cultural heritage on a regional and national scale. During the first years, the focus was on the automatic detection of crop marks and soil marks in cereal fields in satellite and aerial images (Aurdal *et al*., 2006; Trier *et al*., 2009). Several of these detections have been confirmed to be levelled grave mounds, dating to 1500-2500 years ago.

However, methods based on optical images are of limited value in forested areas, since the archaeology tends to be obscured by the tree canopies. However, by using airborne laser scanning (ALS) data, the forest vegetation can be removed from the data, which makes it possible to detect archaeology in a semi-automatic fashion, provided the archaeology manifests itself as details in the digital terrain model (DTM) of the ALS ground returns (Figure 1), and that these details may be described using some kind of pattern.

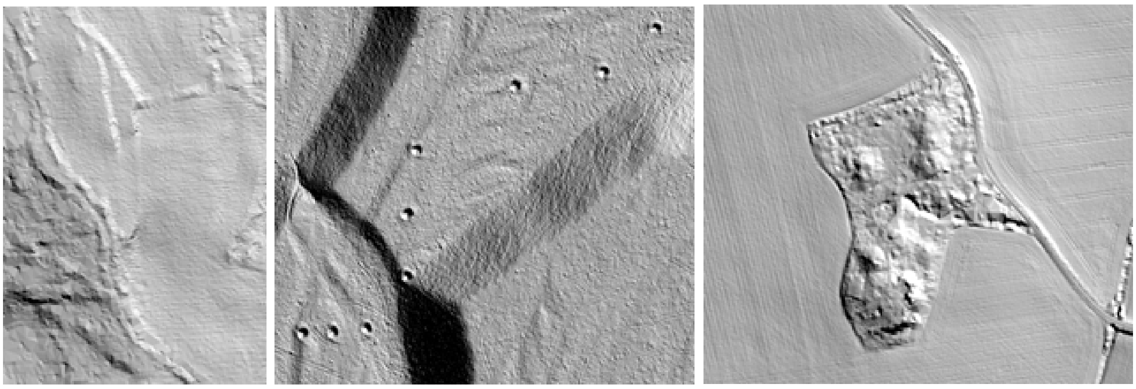


Figure 1. Airborne laser scanning (ALS) data from some Norwegian municipalities. Left: Kongsberg, with stone fences. Middle: Nord-Fron, with pitfall traps for moose hunting. Right: Larvik, with grave mounds.

In 2010, the project started the development of an automatic method for detecting pits in DTMs of ALS ground returns. The method was used to map hunting systems, iron extraction sites and charcoal burning pits (Trier and Pilø, 2012) in two ALS datasets: Olstappen (29 km^2, Nord-Fron municipality, Oppland County, 10 emitted pulses per m^2) and Øystre Slidre (400 km^2, Øystre Slidre municipality, Oppland County, 5/m^2). The results were very good, in part because the pitfall traps and other archaeological pits stood out very well from the surrounding terrain, but also due to the high point density of the ALS data.

A similar method was developed for the automatic detection of mound structures in ALS data and used for semi-automatic mapping of grave mounds in Vestfold. The results were less convincing than for the archaeological pits, partly due to the fact that grave mounds stand out less well from the surrounding terrain. Another challenge was the presence of deciduous trees with dense canopies, which blocked the ALS pulses from reaching the ground. Still, the method was able to make a new discovery of a Viking Age grave field at Omsland Nordre near Kjose in Larvik municipality, Vestfold County (Trier *et al*., 2015b). The method has also been used to support detailed mapping of grave mounds in Larvik and other municipalities in Vestfold County. Further, the method was used to assist the detailed re-mapping of Norway's largest preserved Viking Age grave field at Vang, Oppdal municipality, Sør-Trøndelag County (Trier *et al*., 2015a).

In 2015 the focus has been on the following topics:

1. **Development of an automatic detection method that may be used in semi-automatic detailed mapping of charcoal kilns.** An alternative strategy up until now has been to use a combination of pit detection and mound detection in order to detect parts of the kiln structure. Many kilns have been detected indirectly in this fashion, but many have also been missed, especially those with no distinct central mound and no pits on the perimeter nor the inside. Instead, these kilns often had a circular ditch.

2. **Make available to the archaeologists a pilot portal for running automatic detection of pits and heaps, and eventually also structures that could be charcoal kilns.** The major obstacle up till now has been the very long processing time for automatic heap detection, so a priority has been to identify a less time consuming method. Another problem has been the large number of false positives. A third problem has been limitations on ALS dataset size.

3. **Field verification of semi-automatic detections**. The purpose of this has been two-fold: firstly, to improve the completeness of the archaeological mapping, and secondly, to improve the accuracy of the automatic detection methods.

Preliminary results from the two first topics have resulted in three accepted presentations at international conferences:

1. *44th Computer Applications and Quantitative Methods in Archaeology Conference (CAA 2016)*, 29 March - 2 April 2016, Oslo, Norway

    a. Kermit, Martin Andreas; Trier, Øivind Due. 2016. Towards a national infrastructure for semi-automatic mapping of cultural heritage in Norway.

b. Trier, Øivind Due; Pilø, Lars Holger. 2016. Semi-automatic detection of charcoal kilns from airborne laser scanning data.

2. *European Geosciences Union General Assembly 2016*, Vienna, Austria, 17-22 April 2016:

   a. Trier, Øivind Due; Salberg, Arnt Børre; Pilø, Lars Holger; Tonning, Christer; Johansen, Hans Marius; Aarsten, Dagrun, 2016. Semi-automatic mapping of cultural heritage from airborne laser scanning using deep learning. In: *Geophysical Research Abstracts* 18, p. 5716.

The following previous project results have been published in 2015:

1. Trier, Øivind Due; Pilø, Lars Holger, 2015. Archaeological mapping of large forested areas, using semi-automatic detection and visual interpretation of high-resolution lidar data. In: *CAA2014. 21st Century Archaeology. Concepts, methods and tools. Proceedings of the 42nd Annual Conference on Computer Applications and Quantitative Methods in Archaeology*, Paris, France, 22-25 April 2014. Oxford: Archaeopress, pp. 81-86.

2. Trier, Øivind Due; Pilø, Lars Holger; Johansen, Hans Marius, 2015. Semi-automatic mapping of cultural heritage from airborne laser scanning data. *Sémata* 27. pp. 159-186.

3. Trier, Øivind Due; Zortea, Maciel; Tonning, Christer, 2015. Automatic detection of mound structures in airborne laser scanning data. *Journal of Archaeological Science: Reports* 2, pp. 69-79.

The rest of this note is organized as follows. Chapter 2 describes field validation of charcoal kilns in Lesja municipality, Oppland County. Chapter 3 describes an initial experiment to detect charcoal kilns using deep learning. Chapter 4 contains an abstract that has been accepted for a conference presentation. Chapter 5 describes the current version of the pilot portal. Chapter 6 discusses the major results and gives some recommendations. Appendix A contains photo documentation of selected charcoal kilns at Lesja. Appendix B contains photo documentation of selected grave mounds at Vang, Oppdal municipality, Sør-Trøndelag County.

2 Field validation of charcoal kilns, Lesja municipality, Oppland County

The 17th century saw the establishment of a number of ironworks in Norway, based on the need of the Danish king for iron for ships, armaments and other military purposes. Based on local finds of iron ore, the Danish king issued a royal letter of privilege for an ironwork in Lesja in 1660. The letter states that the ironwork had a circumference from the Lesja rectory to the east and eight old miles (i.e. 60 km by road) to the west towards Romsdalen. Applying this type of circumference to a settled area had large repercussions.

The letter of privilege states that all forests, rivers and waterfalls within the circumference could only be used in accordance with the wishes of the ironwork owners. The timber was needed for the buildings of the ironwork, for charcoal and for firewood; the water was needed to produce power. The farmers were obliged to work in the ironwork if needed, with a payment decided by the owners. They also had to deliver charcoal at a fixed price. Elsewhere in Norway this kind of forced labour had led to considerable unrest among the peasants. This was not the case in Lesja, where farming was marginal, and the possibilities of extra income were welcomed.

The cutting down of the forest started in February 1659, and the first charcoal kilns were presumably constructed shortly after. The local lake was dammed. The first iron production started some years later. In 1718 a visiting official from the mining authorities described the forest as "gandske udhuggen, og resten meget medgaaet" (mostly cut down and the remaining part very affected). The ironwork was never a profitable business as the amount of ore was less than anticipated, and production happened only intermittently until 1812, when the ironwork was finally abandoned.

The remains of the ironwork today consist mainly of the ironwork itself with remains of one of the furnaces, the mines about 13 km further west and large numbers of charcoal kilns in the surrounding forests. In addition, Lake Lesjaskogvatnet, which is in the watershed between east and west, is still dammed at a somewhat higher level than the original lake here. The forest has re-established itself.

In 2013, TerraTec AS, using a Leica ALS70 airborne laser scanner, mapped the entire forested valley in Lesja with LIDAR. The quality of the data is five first returns per m². Hundreds of charcoal kilns were immediately visible in the LIDAR data. They had a varied topographical expression. Some kilns had a ditch surrounding them; some had pits in their circumference, while others had a combination of the two. In addition, some kilns had a low mound inside the ditch/pits or even pits inside the circumference.

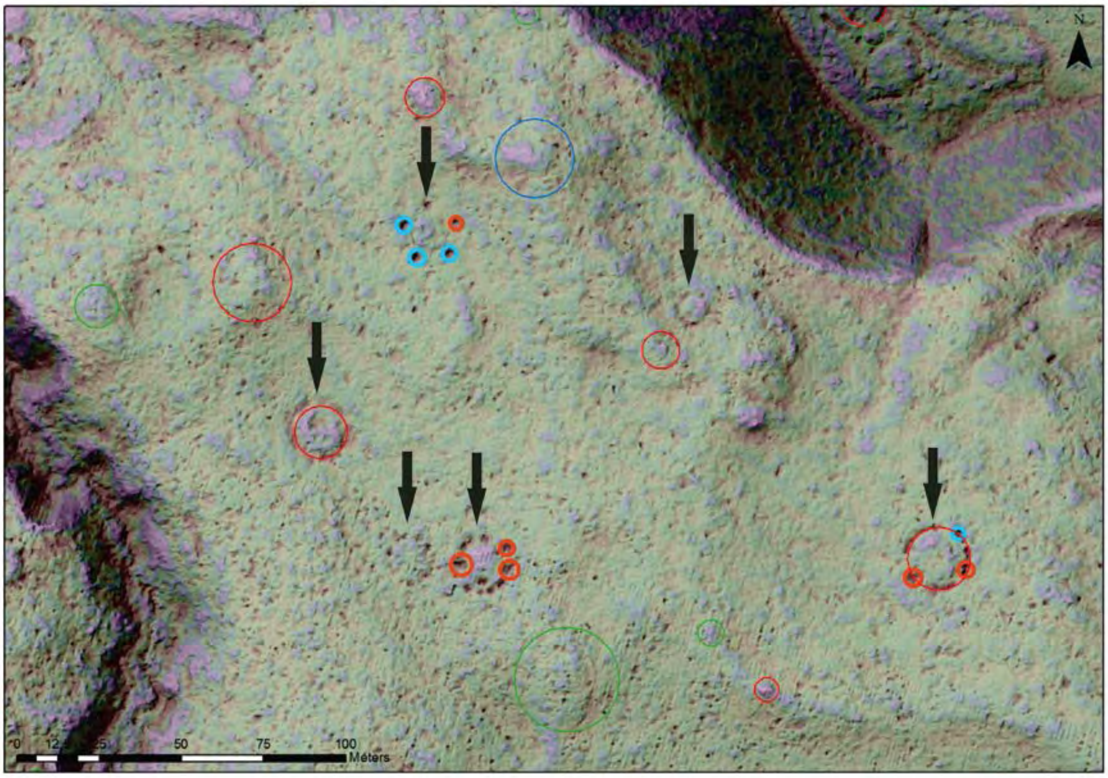


Figure 2. Example of charcoal kilns marked by automated detections of class 4 (orange) and 5 (blue). Thick lines are pit detections, thin lines are mound detections.

A complete visual interpretation of the LIDAR data, supported by automated detection of pits and mounds (Figure 2), has led to the discovery of more than 1000 charcoal kilns in the Lesja valley. 183 charcoal kilns, close to the ironwork, were field validated in 2014. The field validation showed that all charcoal kilns found during visual inspection of the LIDAR data were real. In addition a small number of undetected kilns were found during the ground survey. It was also noted that some of the kilns showed signs of reuse.

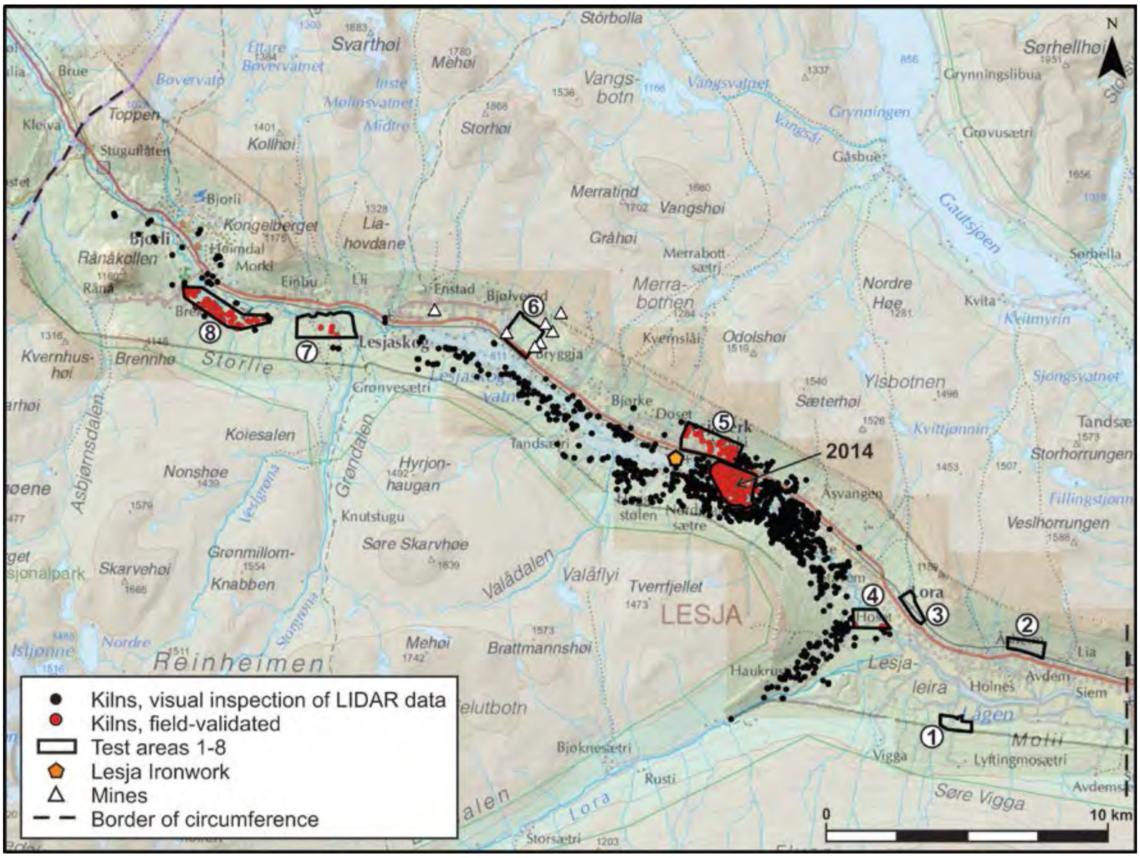


Figure 3. Map of the circumference of the Lesja Ironwork, with the 2014 and 2015 field validation areas marked.

The overall map of the distribution of charcoal kilns (Figure 3) showed some interesting features, which may or may not be an expression of the original distribution of the charcoal kilns. From the outset it was clear that most of the charcoal kilns found during visual inspection were found on old flood plains or glacial washout deposits. Today these plains are covered by open pine forest. This type of vegetation cover gives a high degree of penetration for LIDAR, and thus many ground points. This could imply that kilns in these topographical situations were over-represented on the map. In addition, it should be noted that it was known that agriculture and modern infrastructure had led to the removal of a number of charcoal kilns.

The 2015 field validation aimed to answer specific questions concerning the representativity of the map:

- Area 1, 2 and 3 were chosen to investigate whether the lack of kilns in the area from the Lora River and further east is real or not.

- Area 4 and 7 were chosen to investigate if the scarcity of kilns at the mouth of the Lora and Grøna rivers is real or not.

- Area 5 was chosen to validate the visual interpretation of charcoal kilns in the hillside above the ironwork. These kilns have a different topographical expression, and were only found late in the visual interpretation process. They are only rarely pointed out by the automated detection.

- Area 6 was chosen to investigate whether the scarcity of kilns in the area around the mines is real or not.

- Area 7 and 8 were chosen to examine the scarcity of charcoal kilns between the Grøna River and a clear concentration of kilns 3 km further west.

- Area 8 was also chosen to gain information on the charcoal kilns at the north-western perimeter of the kiln distribution. One important question is if the perimeter of the distribution of charcoal kilns here is real, or if the charcoal kilns change their topographical expression.

The field validation of the specific areas included a systematic surface survey and a check of all objects found during visual interpretation: objects believed to be charcoal kilns, other monuments or just terrain anomalies. The fieldwork was undertaken from 30 August to 11 September 2015. Participants were Frank Røberg (field supervisor), Mats Aspvik, Tessa de Roo and Lars Pilø. Approximately 180 person-hours were used in the field.

Some of the checked areas provided ancient monuments other than charcoal kilns, mostly pitfall traps, which had also been found during the visual inspection. These are not mentioned further in this report.

2.1 Is the lack of kilns from the Lora River and eastwards real?

No charcoal kilns had been found during the visual inspection of areas east of the Lora River. To check if the lack of kilns is real, areas 1, 2 and 3 were chosen for field validation. Area 1 (0.5 km²) and Area 2 (0.6 km²) are quite steep. Area 3 (0.4 km²) is also in a slope, but interspersed with flatter areas (Figure 4).

The field check of the areas 1, 2 and 3 provided no new observations of charcoal kilns. The lack of charcoal kilns to the east of the Lora River thus appears to be real. The area is well within the circumference of the ironwork where charcoal was a forced supply from the farmers. In the case of Area 2 and 3 this indicates an absence of forest here, when the ironwork was established, which would have prohibited charcoal production. The reason for the deforestation here could well be that the available wood had already been used for buildings, fences, firewood etc., as Area 2 and 3 are close to farmsteads existing prior to the ironwork. Charcoal would then have had to be produced in forests at a larger distance from the farms, like in Lordalen or in the southern valley side, opposite the farms, where kilns are abundant. Area 1 also appears untouched by charcoal production. The valley floor in this area used to be a big lake, which was drained out around 1860. As most transport of charcoal would have taken place on sledges during the winter, transport over the frozen ice would have been comparatively straightforward. Maybe this area was also deforested prior to establishment of the ironwork.

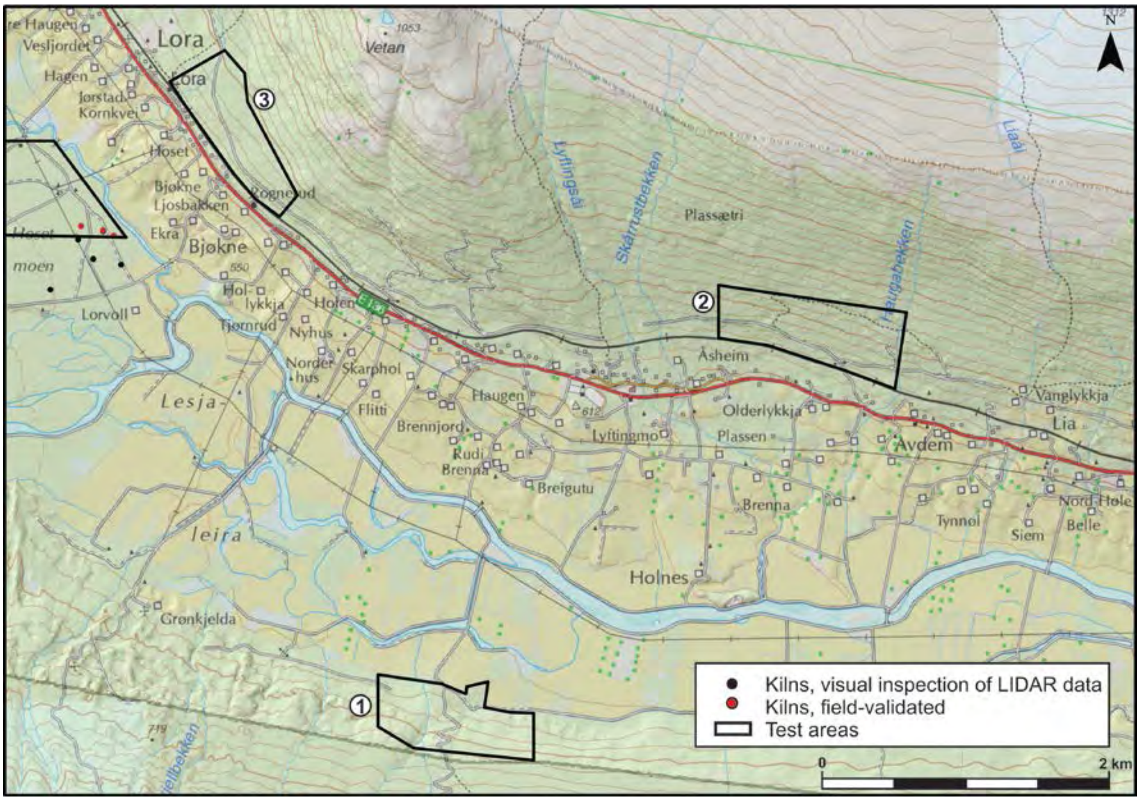


Figure 4. Test areas 1, 2 and 3.

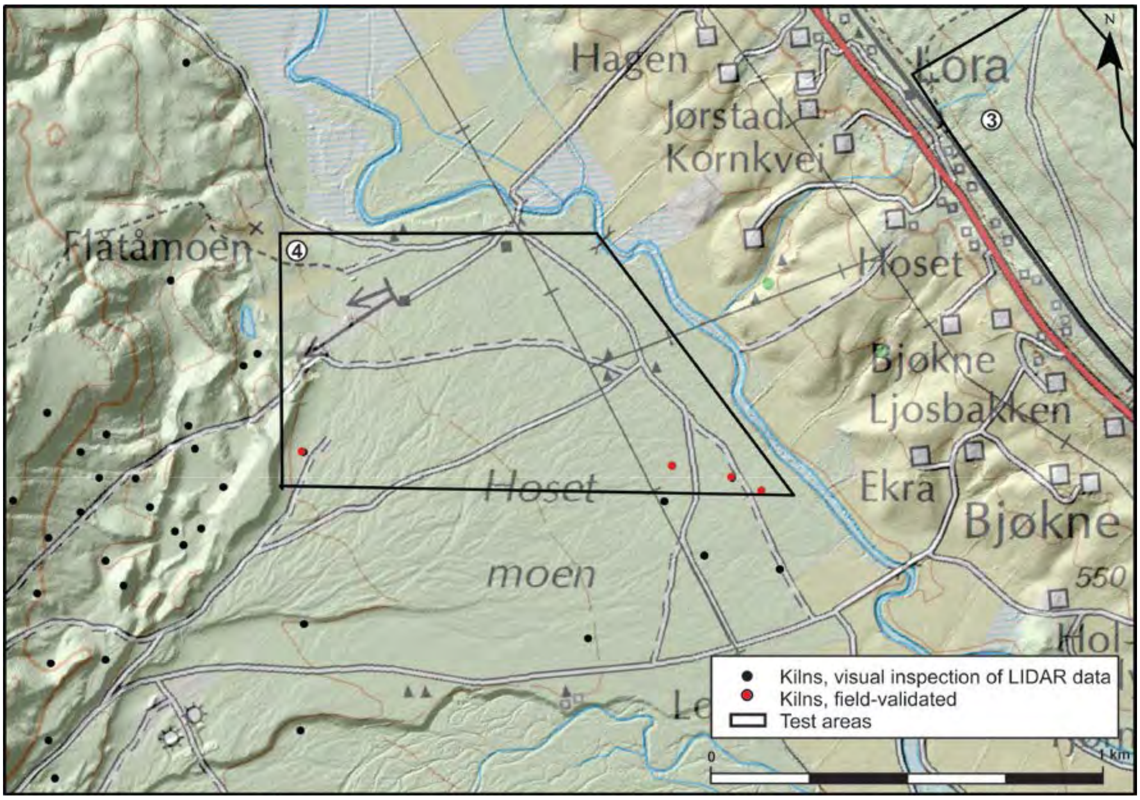


Figure 5. Test area 4. Background hillshade exaggerated by a factor of 3.

2.2 Is the scarcity of charcoal kilns at the mouth of the Lora River real?

The survey in Area 4 (0.7 km²) at the mouth of the Lora River confirmed the two charcoal kilns found here during the visual interpretation (Figure 5). Two additional kilns were found as well. These were difficult to see in the field, and a renewed look at the LIDAR data does not show them either. Otherwise, Area 4 appears to be devoid of charcoal kilns. The floodplain here is much older than the ironwork, and it is probably too high to have been affected by flooding after the establishment of the ironwork (pers. comm. Anders Romundset). However, Area 4 is close to farmsteads, mentioned in historical sources prior to the establishment of the ironwork, just as Area 2 and 3. The scarcity of charcoal kilns here is thus likely caused by deforestation prior to the initiation of charcoal production.

2.3 Is the scarcity of charcoal kilns at the mouth of the Grøna River real?

The survey in Area 7 (1,7 km²) at the mouth of the Grøna River led to the discovery of three additional charcoal kilns in addition to the single kiln found during visual interpretation (see below), but none were found on the river plain at the mouth of the Grøna River (Figure 6). This river plain is lying so low that it could potentially have been affected by flooding after the establishment of the ironwork, at least in the lower part. The absence of charcoal kilns may thus be a result of prior deforestation and/or later flooding.

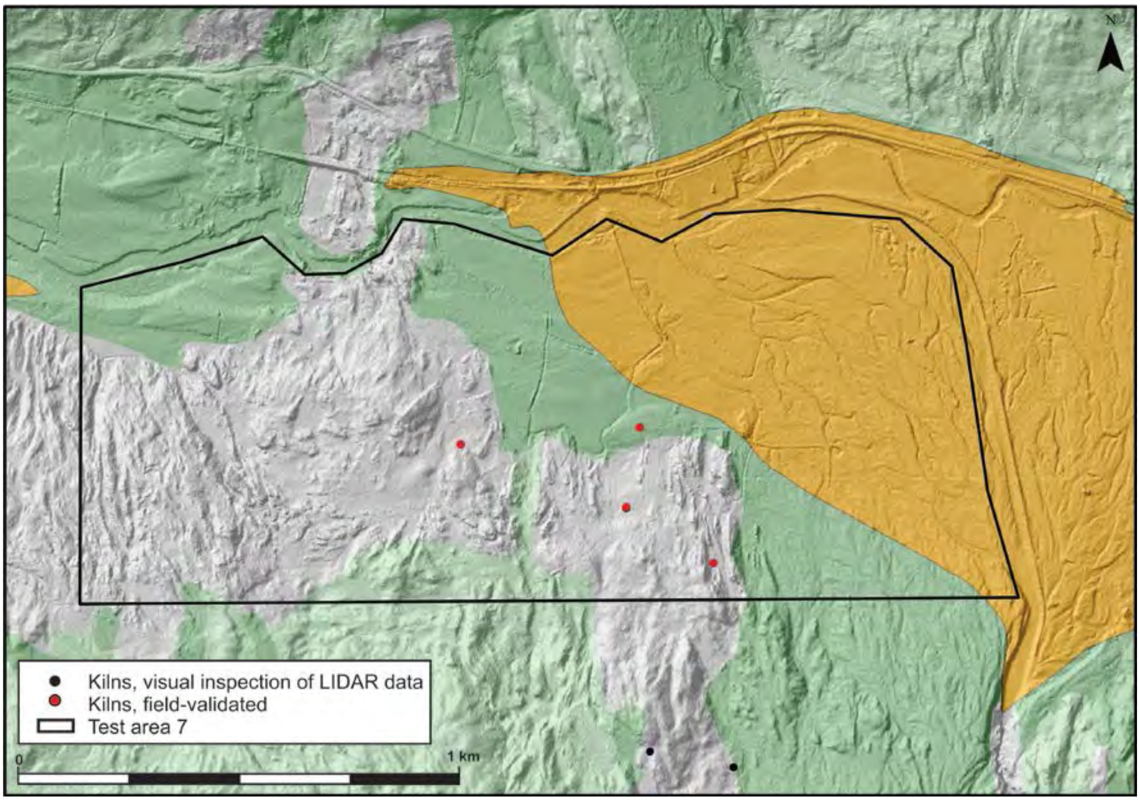


Figure 6. Test area 7, with geology. Background hillshade exaggerated by a factor of 3. Fluvial deposits are orange, thick moraine is dark green, thin moraine is light green, grey is bare rock with only very limited deposits.

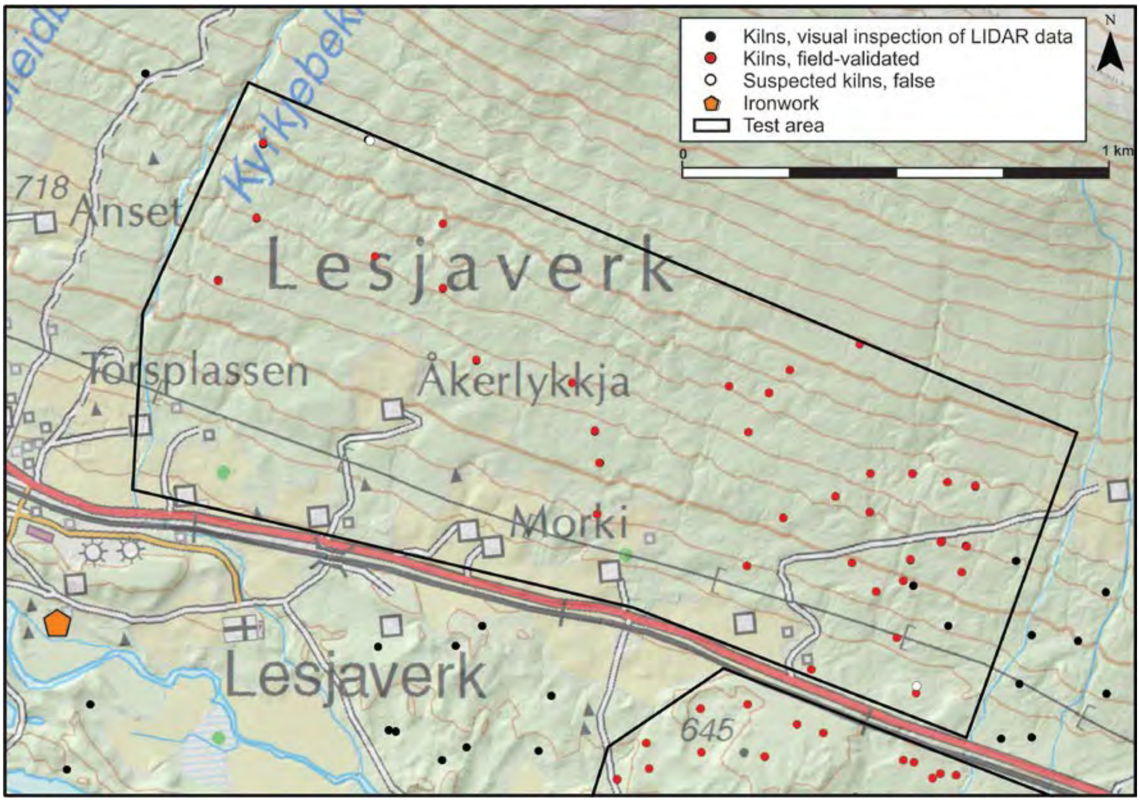


Figure 7. Test area 5.

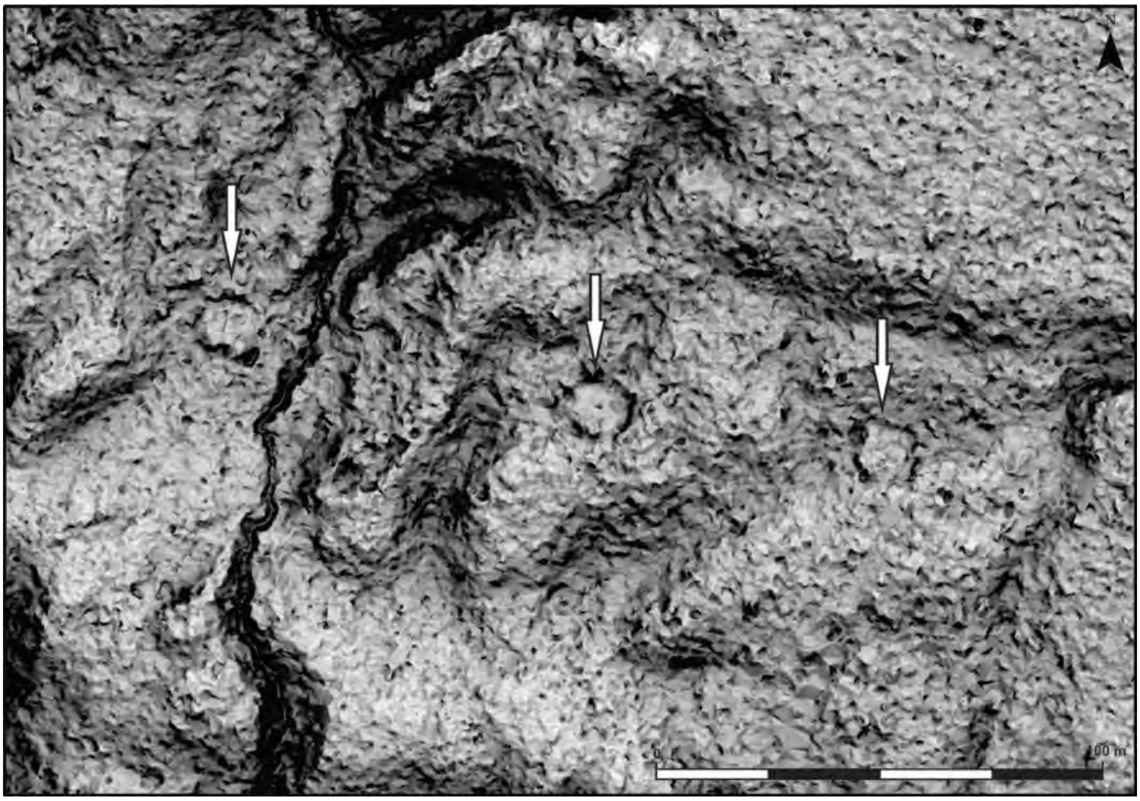


Figure 8. Test area 5, three kilns in detail. The DTM visualization is a combination of sky view factor and slope.

2.4 Are the supposed charcoal kilns in the hillside above the ironwork real?

The field validation of Area 5 (1,8 km²) showed that the supposed charcoal kilns found during the visual inspection of the LIDAR data, but not indicated by automated detection, were in fact real (Figure 7). These kilns have a different topographical expression (Figure 8) than the kilns in flatter areas, being situated in a slope. Two out of 27 of the supposed kilns found during the visual inspection were found to be false during ground-truthing. An additional nine kilns, not found during visual inspection of the LIDAR data, were discovered during ground survey. Two of these kilns had been marked as anomalies during the visual inspection. No false kilns were found in other test areas, and the number of additional kilns found during ground survey is markedly higher in Area 5. This points to more difficult conditions for both visual inspection and automated detection of charcoal kilns situated in slopes.

2.5 Is the scarcity of charcoal kilns in the area close to the mines real?

Area 6 (1.2 km²) only contained three charcoal kilns according to the visual inspection, all in the southernmost part of the survey area (Figure 9). The field validation confirmed this, as all three kilns were found to be real, and no further kilns were discovered inside the area. A possible explanation for the lack of kilns here could be the location of this area close to the iron mines. The mining technique included the use of wood for fire setting in the mines, to make the ore-carrying rock brittle and easier to remove. This firewood would have had to come from somewhere, and the forest close to the mines seems the logical first area to exploit for this purpose.

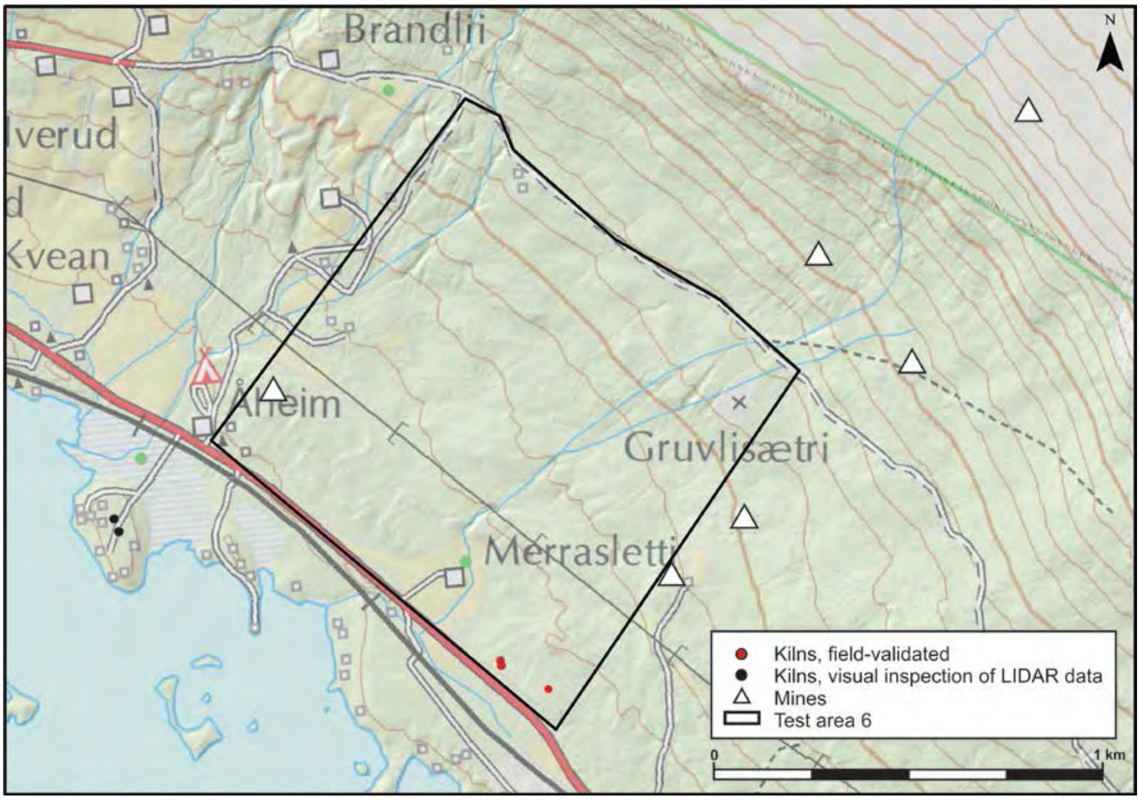


Figure 9. Test area 6.

2.6 Is the scarcity of charcoal kilns from the Grøna River and 3 km westwards real?

This question was investigated through the field validation of areas 7 and 8 (see more on Area 8 below). The visual inspection of the data had led to the discovery of only one charcoal kiln west of the Grøna River. The field validation of Area 7 led to the discovery of three additional charcoal kilns (Figure 6, Figure 10). Two of the additional kilns can barely be discerned in the data, with the benefit of ground-data, while the third is not visible at all.

Area 7 is relatively close to farms established prior to the start of charcoal production, so there is a possibility of deforestation being the explanation for the scarcity of kilns here. Another factor of potential importance is that the geological map of this area indicates an absence of or very thin subsoil. This would imply a low-density forest, and recent aerial photos of this particular area confirm this. A low-density forest would presumably be less attractive for charcoal production in large kilns, as timber would have had to be moved over larger distances than in a high-density forest.

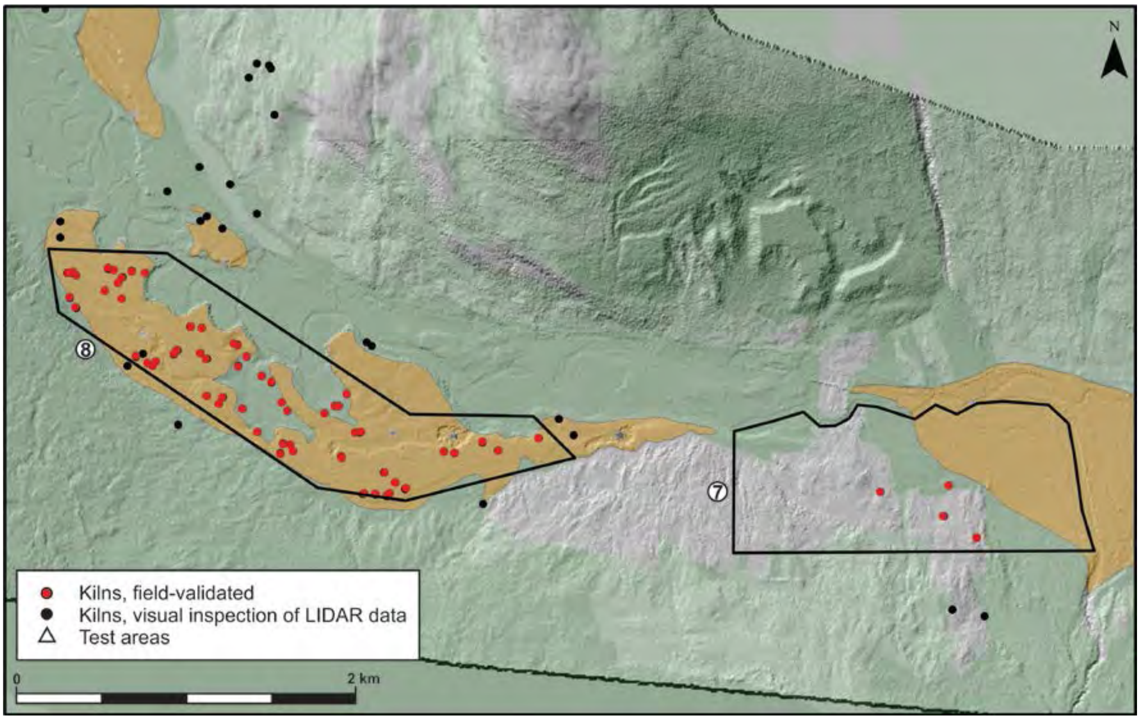


Figure 10. Test areas 7 and 8, with geology. Fluvial deposits are orange, thick moraine is dark green, thin moraine is light green, grey is bare rock with only very limited deposits.

2.7 Are the kilns in the north-western area of the same types as in the central areas?

Area 8 (1.8 km²) contains the largest concentration of charcoal kilns as we approach the north-western perimeter of the distribution of kilns. The ground validation confirmed all charcoal kilns found during visual inspection and added a few additional ones (Figure 10). The kilns were of the same types as in other areas (Figure 11). In general, it could be seen that a larger percentage of kilns in Area 8 had preserved charcoal deposits inside the kiln, than in the 2014 test area close to the ironwork. The kilns in Area 8 are of the same types as elsewhere in Lesja. This makes it clear that the distribution perimeter here is real and not caused by kilns constructed in a way that make them difficult to spot in ALS data. It should be noted however, that a number of kilns might have been removed in the Bjorli area, which is a ski resort, with extensive areas developed for mountain cabins.

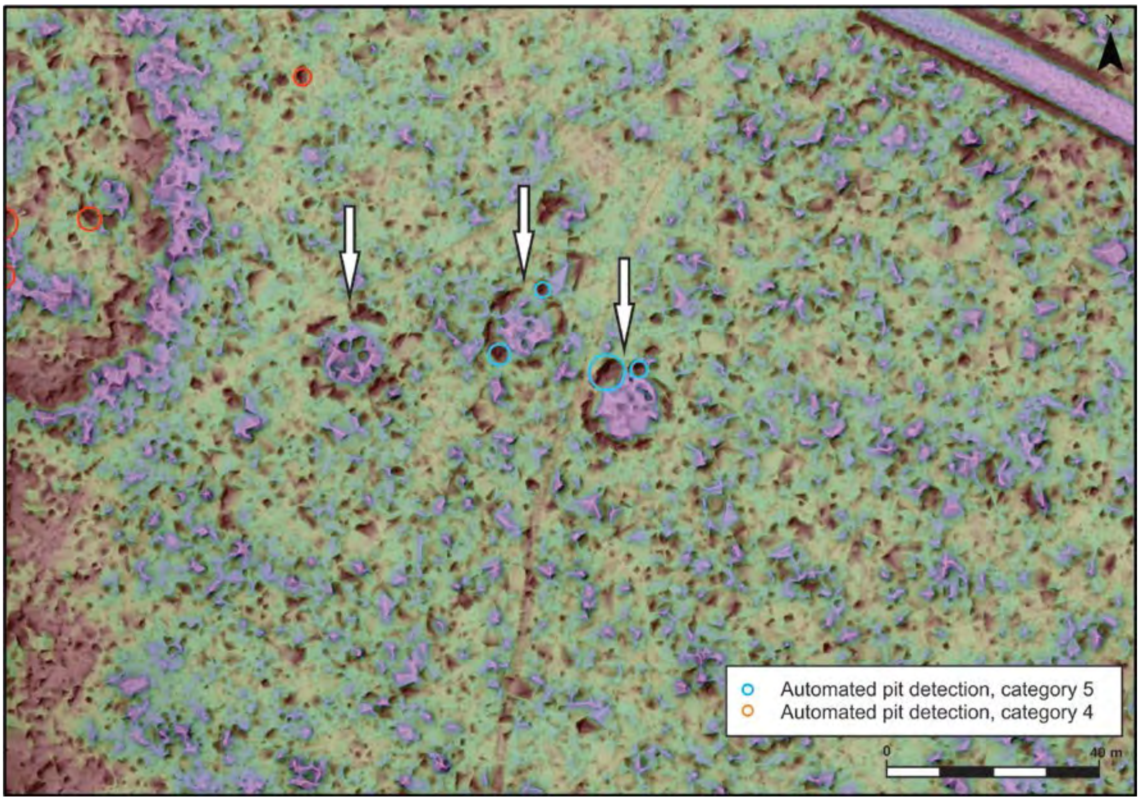


Figure 11. Kilns in test areas 8, with pit detections. Mound detection has not been undertaken in this area yet.

The presence of a large number of charcoal kilns in Area 8 is somewhat surprising, as we have a 1721 source, which indicates that the timber in the north-western perimeter of the circumference was not used for the ironwork. The area is within the circumference of the ironwork and so the timber could only be used for other purposes, if the ironwork did not have access to or use for the timber. In the 1721 letter, the owner of the three main farms here (Rånå, Bjorli and Stuguflotten) state, that it was not possible to transport the charcoal to the ironwork, due to a long and difficult road. For this reason they were allowed to deliver the timber to a sawmill just northwest of the farms. The letter indicates that the standing forest here was of old age and ready to fall down, though this may be a ploy to get permission. There is no indication of charcoal production taking place here prior to the letter. It may be that Area 8 is more closely connected to the farms further east, and that the 1721 letter refers to areas further northwest closer to the three farms mentioned in the letter. However, even in these areas charcoal kilns area present, and the recipient of this charcoal would have been the Lesja Ironwork.

2.8 Discussion

A number of factors affect the distribution of charcoal kilns as they have been mapped today. The historical factors are:

- The presence of farms with an obligation to deliver charcoal to the ironwork, that is farms located within the circumference of the ironwork

- The presence of forested areas for production of charcoal

- The access to the forested areas - ownership and practical issues

The map of the location of farms established prior to the ironwork, combined with the distribution of charcoal kilns, shows that the immediate areas surrounding pre-ironwork farms have very few charcoal kilns (Figure 12). This is best explained by prior use of the forest in these areas for buildings, fences, firewood etc.

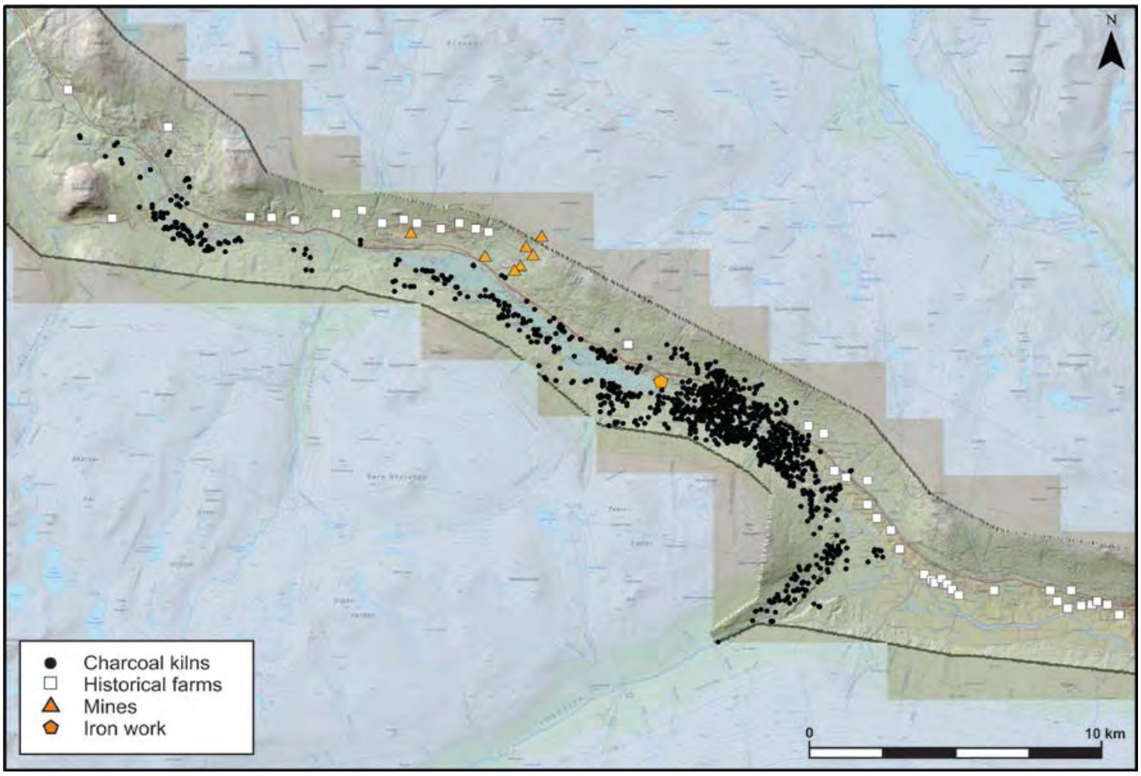


Figure 12. The circumference of the Lesja Ironwork, with the ironwork, mines, charcoal kilns and historical farms.

Based on the results of the 2015 ground validation it appears that the area to the east of the Lora River was largely deforested prior to the start of charcoal production. In addition, areas on the northern side of the Lora river mouth appear to have been partly deforested prior to charcoal production.

Based on the ground validation of the area west of the Grøna River it appears that charcoal producers tried to avoid low-density forests. This is probably because the production of charcoal in large kilns would increase work costs connected with the transport of felled timber to the kiln.

The area close to the iron mines has no charcoal kilns. This is likely because the wood here was used for fire setting in the mines, and was not available for charcoal production.

The presence of only a very few charcoal kilns in the hillside between the ironwork and the mines was not directly addressed during the 2015 fieldwork. The field validation of Area 5 did confirm the presence of charcoal kilns dug into the slope in the hillside north of the ironwork. The survey found more charcoal kilns here, than detected during the visual inspection of the LIDAR data. However, the presence of less than a handful of detected kilns in the hillside between Area 5 and 6 does not suggest that this area was much used for charcoal production, even when considering that there may be more kilns here than found during visual interpretation. The farms in this area were established after the start of the ironwork and were owned by the ironwork. The farmers here worked in the ironwork and paid land rent. They were thus probably not subject to the forced delivery of charcoal. They would likely not have had the time either as they were paid labourers, working long hours. The farmers produced the charcoal outside the short agricultural season, when they had spare time. The 1718 source describing the forest as being largely cut down suggests that the timber here may have been used for purposes other than charcoal in the ironwork, e.g. for constructions.

There are a number of charcoal kilns by the lake below the mines and the farms belonging to the ironwork. It is not clear why these areas were used for charcoal production, if the farms here were not obliged to provide charcoal, or if the timber was otherwise used for constructions.

Charcoal kilns may have been destroyed or obscured after they were constructed:

- Due to new fields in previously forested areas
- The kilns may have been destroyed by modern infrastructure and development
- The kilns may have been destroyed or obscured by flooding

New fields have been made in the woods in the areas with charcoal kilns. Most of these fields are rather small, but have led to the destruction of all kilns located there. It may be that these destroyed kilns can be found as crop marks or soil marks, but the fields are mainly used for grass production, which is not beneficial to optical detection.

Obviously, modern infrastructure and development has led to the destruction of charcoal kilns. There is now a modern highway and a railroad track running through the entire length of the valley. The road and the railroad are running parallel to each other and are mostly situated close to each other. The impression from field validation, which has taken place close to the road and railroad, is that they have not led to much disturbance outside their actual extent.

The destruction or obscuring of charcoal kilns because of flooding has been raised as a possibility above. However, the 2014 field validation demonstrated the presence of a number of charcoal kilns very close to the Lågen River. If flooding is to have been a factor in the removal of kilns, it is hard to explain that these kilns have survived until present. In addition, the ironwork is situated very close to the watershed, and flooding is thus less likely.

2.9 Conclusions

The map of the charcoal kilns associated with the Lesja Ironwork has been constructed by visual interpretation of LIDAR-data, supported by automated detection of pits and mounds. The kiln data set has been field validated in nine different areas, with the aim to investigate how reliable the data is. This field validation has shown that the constructed map of the charcoal kilns associated with the Lesja Ironwork is largely reflecting the original distribution of kilns. A small number of kilns have been removed by modern infrastructure and development, and by agriculture. Not all kilns are found during the visual inspection of the data (false negatives), but there are very few false positives. The present number of field-validated kilns is 289, while the number of kilns found by visual interpretation, aided by automated detection, but not field validated is approximately 850. Thus, the total number of charcoal kilns in Lesja was probably above 1150.

The absence of kilns in the areas surrounding the 17th century farm settlement is very likely an indicator that these areas already were deforested prior to the establishment of the ironwork. The presence of kilns in the remaining areas in the valley and in the hillsides suggests that the valley was largely deforested during the 150 years that the ironwork was in use, and this is supported by written sources. Only the northern hillside just west of the ironwork appears to have been exempt to charcoal production, probably because the ironwork itself owned the area. Otherwise, the only other areas without charcoal production were the upper part of the hillsides. Some of the kilns in the validated areas appear to have been used on two occasions, suggesting that the forest came back after the first wave of charcoal production, and was used again for the same purpose.

The LIDAR based mapping of charcoal kilns has yielded valuable new information on the extent and character of the landscape impact of the ironwork at Lesja. The mapping has been low cost, but with a high level of precision. Doing this job in a traditional way with ground-based fieldwork would have been very expensive. In fact, it would probably not have been undertaken, as the charcoal kilns are not protected monuments, and therefore a very low on the priority list.

The Lesja Ironwork survey is an important example of the power of remote sensing.

3 Semi-automatic mapping of cultural heritage from airborne laser scanning using deep learning

The abstract has been accepted for presentation at the European Geosciences Union General Assembly 2016, Vienna, Austria, 17-22 April 2016.

3.1 Abstract

This chapter proposes to use deep learning to improve semi-automatic mapping of cultural heritage from airborne laser scanning (ALS) data.

Automatic detection methods, based on traditional pattern recognition, have been applied in a number of cultural heritage mapping projects in Norway for the past five years. Automatic detection of pits and heaps have been combined with visual interpretation of the ALS data for the mapping of deer hunting systems, iron production sites, grave mounds and charcoal kilns.

However, the performance of the automatic detection methods varied substantially between ALS datasets. For the mapping of deer hunting systems on flat gravel and sand sediment deposits, the automatic detection results were almost perfect. However, some false detections appeared in the terrain outside of the sediment deposits. These could be explained by other pit-like landscape features, like parts of river courses, spaces between boulders, and modern terrain modifications. However, these were easy to spot during visual interpretation, and the number of missed individual pitfall traps was still low.

For the mapping of grave mounds, the automatic method produced a large number of false detections, reducing the usefulness of the semi-automatic approach. The mound structure is a very common natural terrain feature, and the grave mounds are less distinct in shape than the pitfall traps. Still, applying automatic mound detection on an entire municipality did lead to a new discovery of an Iron Age grave field with more than 15 individual mounds. Automatic mound detection also proved to be useful for a detailed re-mapping of Norway's largest Iron Age grave yard, which contains almost 1000 individual graves.

Combined pit and mound detection has been applied to the mapping of more than 1000 charcoal kilns that were used by an iron work 350-200 years ago. The majority of charcoal kilns were indirectly detected as either pits on the circumference, a central mound, or both. However, kilns with a flat interior and a shallow ditch along the circumference were often missed by the automatic detection method.

The successfulness of automatic detection seems to depend on two factors: (1) the density of ALS ground hits on the cultural heritage structures being sought, and (2) to what extent these structures stand out from natural terrain structures. The first factor may, to some extent, be improved by using a higher number of ALS pulses per square meter. The second factor is difficult to change, and also highlights another challenge: how to make a general automatic method that is applicable in all types of terrain within a country.

The mixed experience with traditional pattern recognition for semi-automatic mapping of cultural heritage led us to consider deep learning as an alternative approach. The main principle is that a general feature detector has been trained on a large image database. The feature detector is then tailored to a specific task by using a modest number of images of true and false examples of the features being sought. Results of using deep learning are compared with previous results using traditional pattern recognition.

3.2 Data and methods

3.2.1 Deep convolutional neural networks

Detection and classification of objects in remote sensing images are often challenging tasks (e.g., see Larsen *et al*., 2013; Trier and Pilø, 2012; Solberg *et al*., 2007; Xu *et al*., 2010; Zhang *et al*., 2014), mainly since it is hard to design features that are able to capture the visual information needed for robust detection and recognition. A common characteristic of the features applied in remote sensing recognition applications is that they are to a great extent handcrafted and relatively simple (e.g., Larsen *et al*., 2013; Brekke and Solberg, 2005). The limited information captured by the handcrafted features has often resulted in a reduced performance metric compared to recognition performed by humans.

Krizhevsky *et al.* (2012) demonstrated that convolutional neural networks (CNNs) obtained substantially higher image classification accuracy on the ImageNet Large Visual Recognition Challenge (ILSVRC) (Russakovsky *et al*., 2015). Their success was a result from training a large CNN on 1.2 million labelled images, and by using more efficient strategies for training the network (e.g. rectifying linear units and ”dropout” regularization”). In order to train a CNN with performance metrics comparable to the ones reported by Krizhevsky *et al*. (2012), a substantial amount of labelled training images is needed, and preferably, a Graphics Processing Unit (GPU) in order to speed-up the processing time. For many applications this is not feasible. However, a “small data approach” is feasible. It has been successfully demonstrated that the features extracted from a deep CNN, carefully trained on the large ImageNet database, may be applied as generic feature representations and thereby applied to perform a wide variety of vision tasks (e.g., see Razavian *et al*., 2014; Chatfield *et al*., 2014; Azizpour *et al*., 2015; Salberg 2015).

The approach we will apply to detect cultural heritages from airborne laser data is such “small data approach”, where we apply a deep CNN to extract image features from a digital elevation model derived from the laser data.

3.2.2 Feature extraction

The feature extraction module is based on the CNN applied by Krizhevsky *et al*. (2012) to win the 2012 ImageNet contest. Since the ImageNet database consists of variable-resolution images, Krizhevsky *et al*. down-sampled the images to a fixed resolution of 256×256 by first rescaling the shorter side to a length of 256, and then cropped out the 256×256 central patch of the resulting image. As a final pre-processing step the mean activity over the training set was subtracted from each pixel. The CNN proposed by Krizhevsky *et al.* (2012) has 60 million parameters, where the last hidden layer (the layer prior to output category mapping) consisted of 4096 features. The CNN classified an image into one of 1000 categories, and was trained using 1.2 million training images and 50,000 validation images from the ImageNet database.

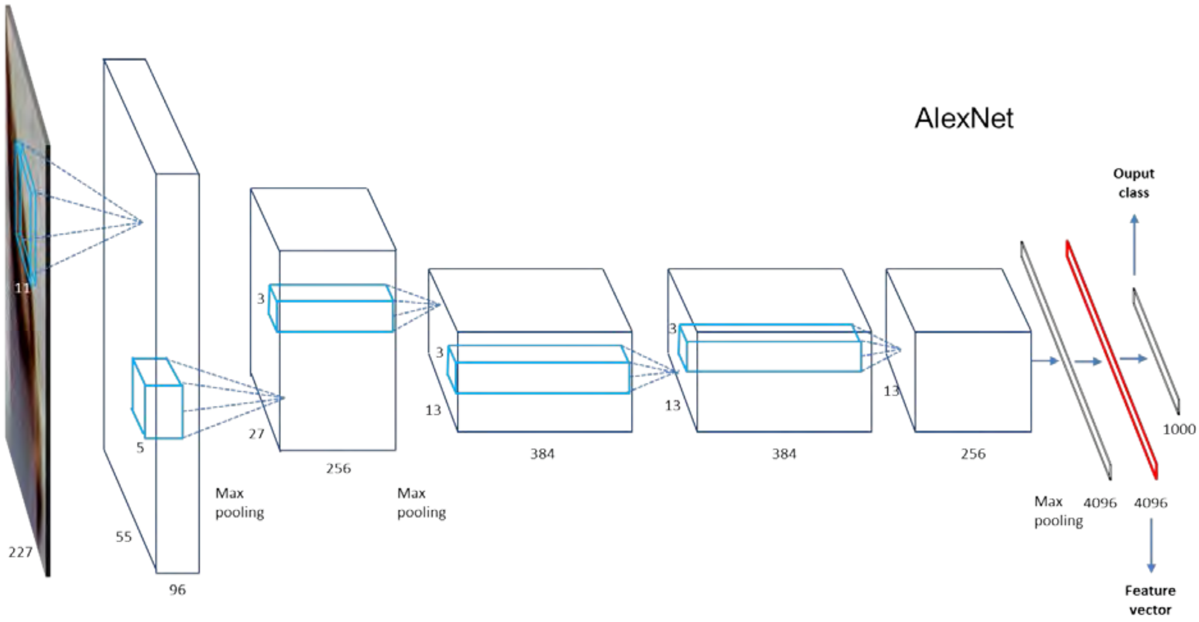


Figure 13: AlexNet, the convolutional neural network applied by Krizhevsky *et al*. (2012). One of the two vector vectors of dimension 4096 at the end of the network is applied as feature vectors.

In order to apply the CNN proposed by Krizhevsky *et al*. (2012), we extract overlapping subimages of 150×150 pixels (30×30 m) with a stride of 1 meter across the whole DTM. These subimages are then resized to 256×256 to fit the input dimension of the CNN, and sent through the network. Since the CNN is not trained to distinguish cultural heritages from look-alikes, we consider the last or second last hidden layer. The 4096-dimensional feature vector (Figure 13) is extracted from this layer for each object proposal by propagating the resized subimage through the CNN.

3.2.3 Linear support vector machine

The 4096-dimensional feature vectors extracted by the CNN are first scaled to unit norm, and then applied as input to a linear SVM classifier. The reason for choosing a linear classifier is that the dimension of the input feature vectors is high, and we therefore expect them to be linearly separable in the feature space. To perform the SVM classification we apply the Scikit Learn library in Python. The cost parameter in the SVM classifier was equal to 10.

3.2.4 Training data

The training data consisted of a set of 375 ground validated charcoal kiln locations at Sandom in Lesja municipality, Oppland County, Norway, with a corresponding DTM derived from ALS measurements. From the same area we also have 10027 lookalikes locations. CNN features were extracted from the subimage corresponding to each kiln and lookalike and used to train a linear SVM.

3.3 Preliminary results - semi-automatic detection of kilns

We now apply the CNN-SVM approach to detect kilns in DTM images.

3.3.1 Confusion matrices

Using the trained SVM, each feature vector was classified as kiln or lookalike. The confusion matrix (Table 1) shows that we are able to predict the kilns with very high accuracy, even though the classification is very unbalanced (375 kilns versus 10027 lookalikes). The average accuracy was 99.1%.

Table 1: Confusion matrix obtained from 20-fold cross validation.

	Predicted kiln	Predicted lookalike	Classification error
True kiln	317	58	0.155
True lookalike	35	9992	0.0035

3.3.2 Detection results

To demonstrate the kiln detection scheme we consider a 5000×5000 pixel DTM image (corresponding to 1×1 km), and map all detected kiln locations (Figure 14). For kilns that are easy to detect visually by a human in a hillshade image (or DTM image), the proposed method detects them as well (Figure 15). However, the CNN-SVM approach also detects some false objects (Figure 16), and misses some kilns (Figure 17). Many of the missed kilns are difficult to detect for a non-trained human.

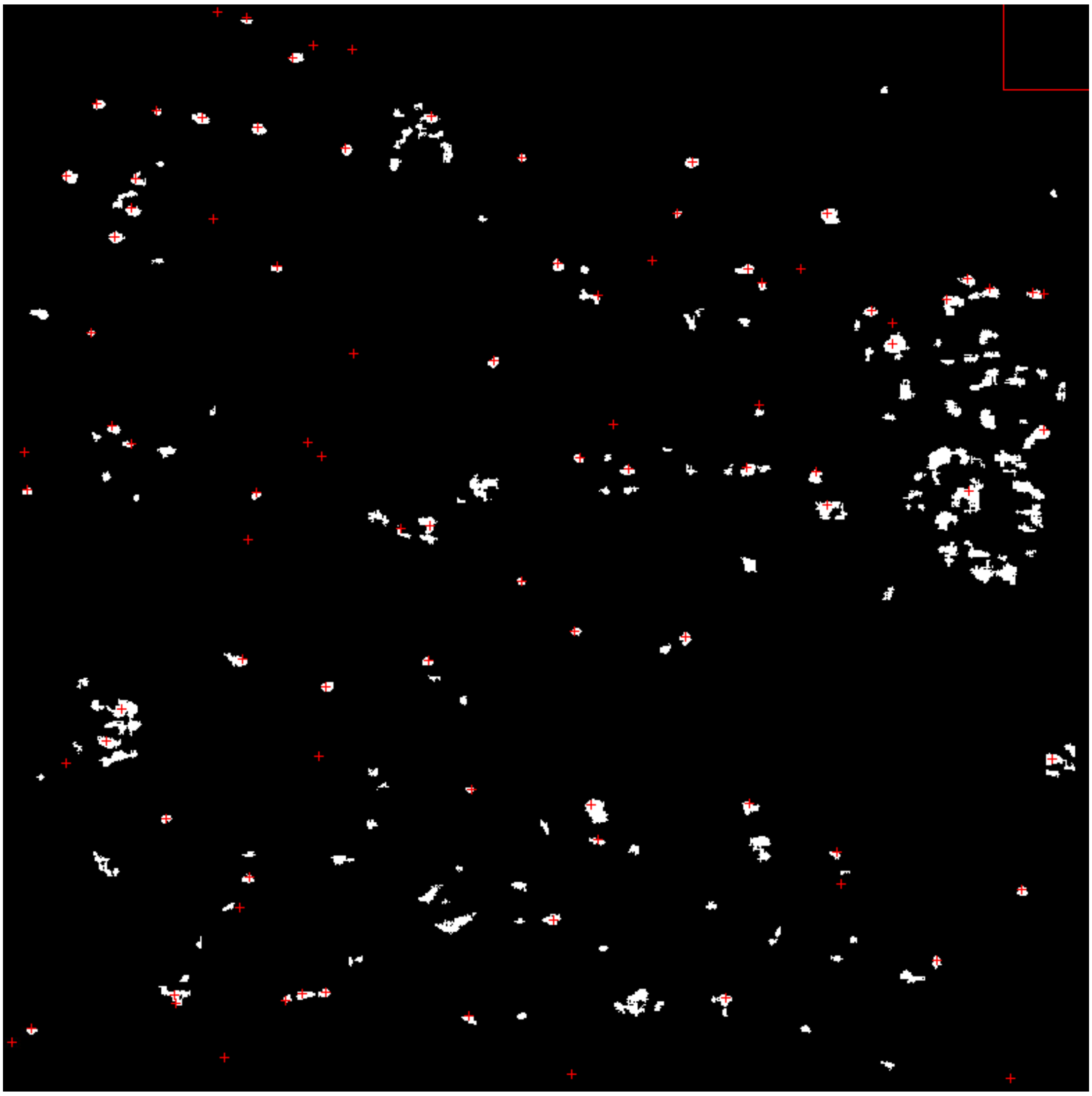


Figure 14: Map of detected kilns (white areas). Red crosses indicate ground validated kiln locations.

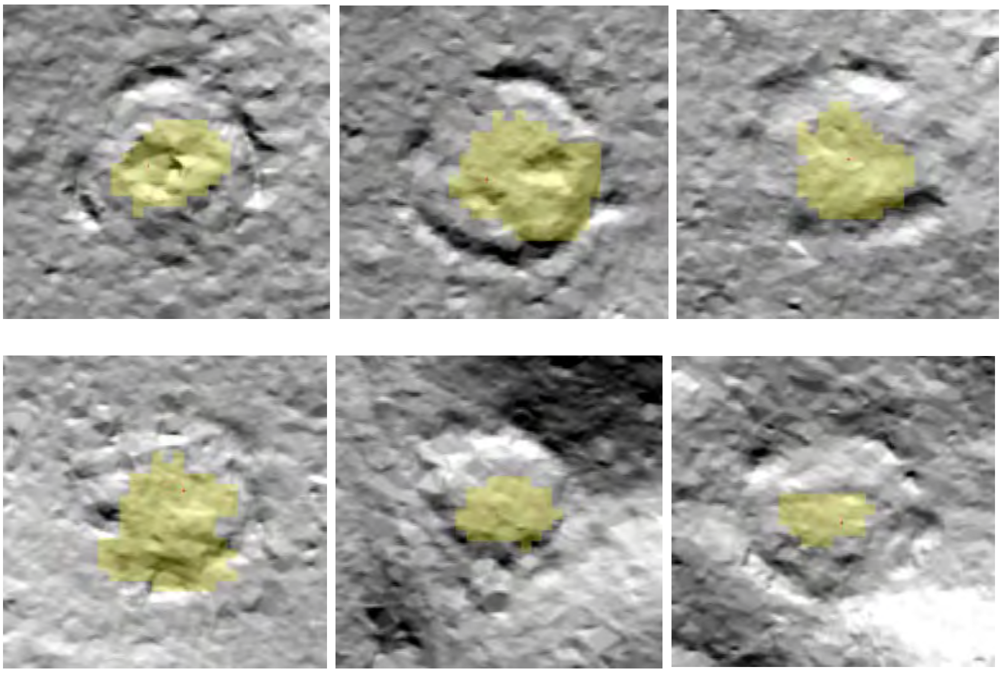


Figure 15. Examples of correct detections.

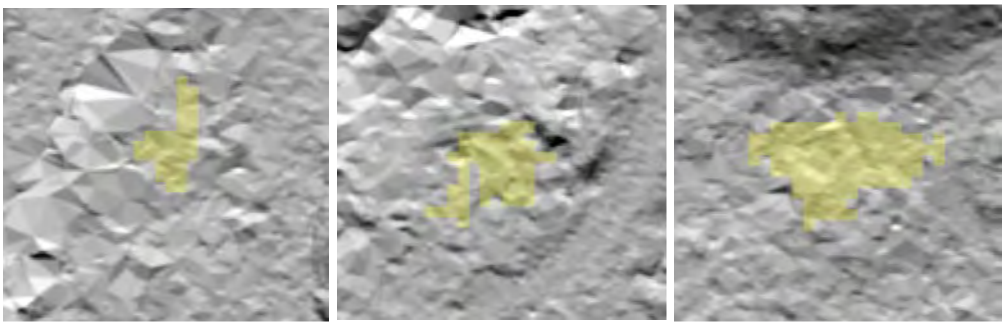


Figure 16. Examples of false positives.

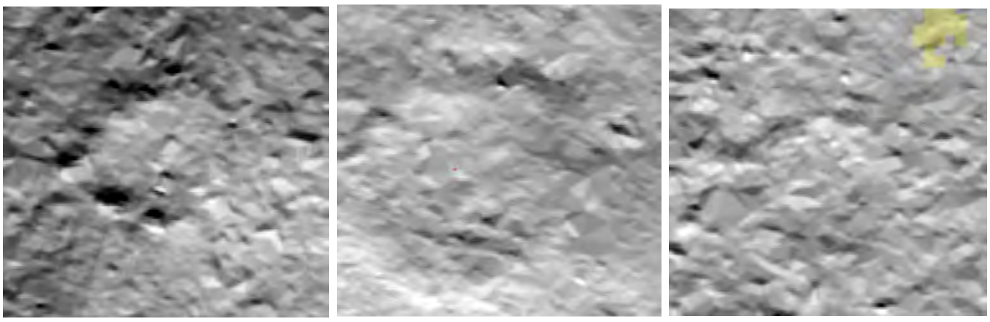


Figure 17. Examples of missed kilns.

3.4 Discussion and conclusions

We have demonstrated that deep CNNs may be well suited to perform object recognition tasks in ALS images. The CNN+SVM based system was able to detect 84.5% of the true kilns. Of the structures that the method reported to be kilns, 90%

were true kilns and 10% were lookalikes. Many of the true kilns that were missed are also difficult to detect for a non-trained human reader. Please note this performance is evaluated using cross-validation on the training data, and all the kilns are located in the same area.

The design of the CNN is a challenging task. We have applied the same net as Krizhevsky *et al*. (2012), and applying this CNN architecture to compute the features is most likely not ideal for our application since neither ALS images nor kilns are present in the ImageNet database. There are many aspects of the CNN that need to be evaluated, e.g. the use of multiple crops, including rotation of the object, the dimension of the cropped image, the use of other channel combinations, and to perform a fine-tuning of the network instead of applying an SVM at the network output. All details are of great importance with respect to the performance. Moreover, there is no colour information in the ALS images, which is not the case in the ImageNet database, and the objects are highly special (kilns). An increase in performance is expected if using a CNN with optimal network architecture, trained on a large collection of relevant images.

A shortcoming that needs to be addressed is the lack of exact locations of the detected kilns in the CNN-based approach (Figure 14). This is due to the fact that the net recognizes whether a kiln is present in a subimage, but not the precise location within the subimage. A method that may increase the locational accuracy, and, as a result, may be able to distinguish two nearby kilns, is needed.

The CNN-SVM approach is remarkable generic, and may be applied to other cultural heritage structures as well. We have applied it to successfully detect pitfall traps in ALS data from Olstappen, with the same degree of accuracy as for the kilns in Lesja.

As a conclusion, the proposed method is better than our previous attempts at semi-automatic charcoal detection based on traditional pattern recognition methods. The new method detects more true charcoal kilns and has very few false positives.

3.5 Acknowledgement

This research was funded by the Directorate for Cultural Heritage in Norway (Riksantikvaren).

4 Semi-automatic detection of charcoal kilns from airborne laser scanning data

Øivind Due Trier (NR), Lars Holger Pilø (NR)

The below abstract has been accepted for presentation at the 44th Computer Applications and Quantitative Methods in Archaeology Conference (CAA 2016) in Oslo, Norway, 29 March - 2 April 2016.

4.1 Abstract

The 17th century saw the establishment of a number of iron works in Norway, based on the need of the Danish king for iron for ships, armaments and other military purposes. The iron works at Lesja, Oppland County, was established 1660. Surveys in connection with cultural heritage management work have pointed to the presence of large numbers of charcoal kilns in the area surrounding the Lesja Iron Works. It was not known, however, what the total number of preserved kilns was, if they showed sign of reuse, and how they were distributed throughout the landscape.

In 2013 the entire forested valley in Lesja was mapped by ALS with five first returns per m². The initial visual interpretation of the ALS data, focusing on the central area, yielded about one thousand possible charcoal kilns. All were round, with a diameter between 10 and 20 m. However, the edge of the kilns had a varied topographical expression. Some kilns had a ditch surrounding them, some had pits, and some had a combination of the two. In addition some kilns had a low mound inside the ditch/pits or even pits inside the circumference.

In order to conduct a complete mapping, covering the different shapes of charcoal kiln, several detection methods are used: (1) mound detection, (2) pit detection, (3) circular ditch detection, and (4) partial ditch detection. Although many individual charcoal kilns are missed by the automatic detection methods, many are also detected, leading the archaeologist to look for additional charcoal kilns nearby. In conclusion, the automatic detection methods are improving the quality of visual interpretation of the ALS data, and make the field work more efficient.

5 Towards a national infrastructure for semi-automatic mapping of cultural heritage in Norway

Martin Kermit (NR), Jarle Bauck Hamar (NR), Øivind Due Trier (NR)

This chapter describes a pilot portal for semi-automatic detection of archaeological pits and heaps in airborne laser scanning (ALS) data.

The below abstract has been accepted for presentation at the 44th Computer Applications and Quantitative Methods in Archaeology Conference (CAA 2016) in Oslo, Norway, 29 March - 2 April 2016.

5.1 Abstract

Recently, the Norwegian government decided to finance a new national digital terrain model (DTM) based on airborne laser scanning (ALS) at 2 pulses per m² in forested areas and automatic image matching above the tree line. This may open up for semi-automatic mapping of cultural heritage in any region of interest in Norway, provided that the cultural heritage being sought manifests itself in the DTM. However, this calls for the development of a national infrastructure combining the storage and retrieval of ALS data with automatic detection methods.

A pilot web portal for this infrastructure has been developed for use by archaeologists in some county administrations in Norway. The user specifies an area of interest, and selects which types of cultural heritage to look for. Since the new national DTM is not implemented yet, the user will need to upload an ALS data set. As the processing of large ALS data sets may be time consuming, the user will be notified when the task has been completed by an e-mail, which also contains a link where the processing result in the form of vector files may be downloaded.

Currently, semi-automatic detection of the following types of cultural heritage is supported: grave mound, pitfall trap, charcoal burning pit, and charcoal kiln. We plan to add semi-automatic detection of hollow ways and stone fences.

The output is one set of files for each type of cultural heritage. Within each type of cultural heritage, the detection results are grouped into six levels of confidence. The detections should be viewed and evaluated successively by an experienced archaeologist; starting with the highest confidence level.

The pilot portal is already a useful tool for archaeologists in the participating pilot counties in Norway, and demonstrates the need for a national infrastructure for processing of ALS data.

5.2 Pilot portal user interface

NR has developed a pilot web service for running automatic detection of pit and heap structures in airborne laser scanning (ALS) data. The user uploads ALS data sets, preferably as a collection of compressed laz files, but uncompressed las files are also allowed. From the set of recently or previously uploaded ALS datasets, the user may then select to perform an automatic detection of pits and/or heaps. The detection result is emailed to the user as a collection of ESRI Shape files.

5.2.1 Logging on

The pilot portal is available at:

http://cultsearcher2.nr.no

A user name and a password are required (Figure 18). Only the project partners (including Riksantikvaren) may obtain usernames/passwords.

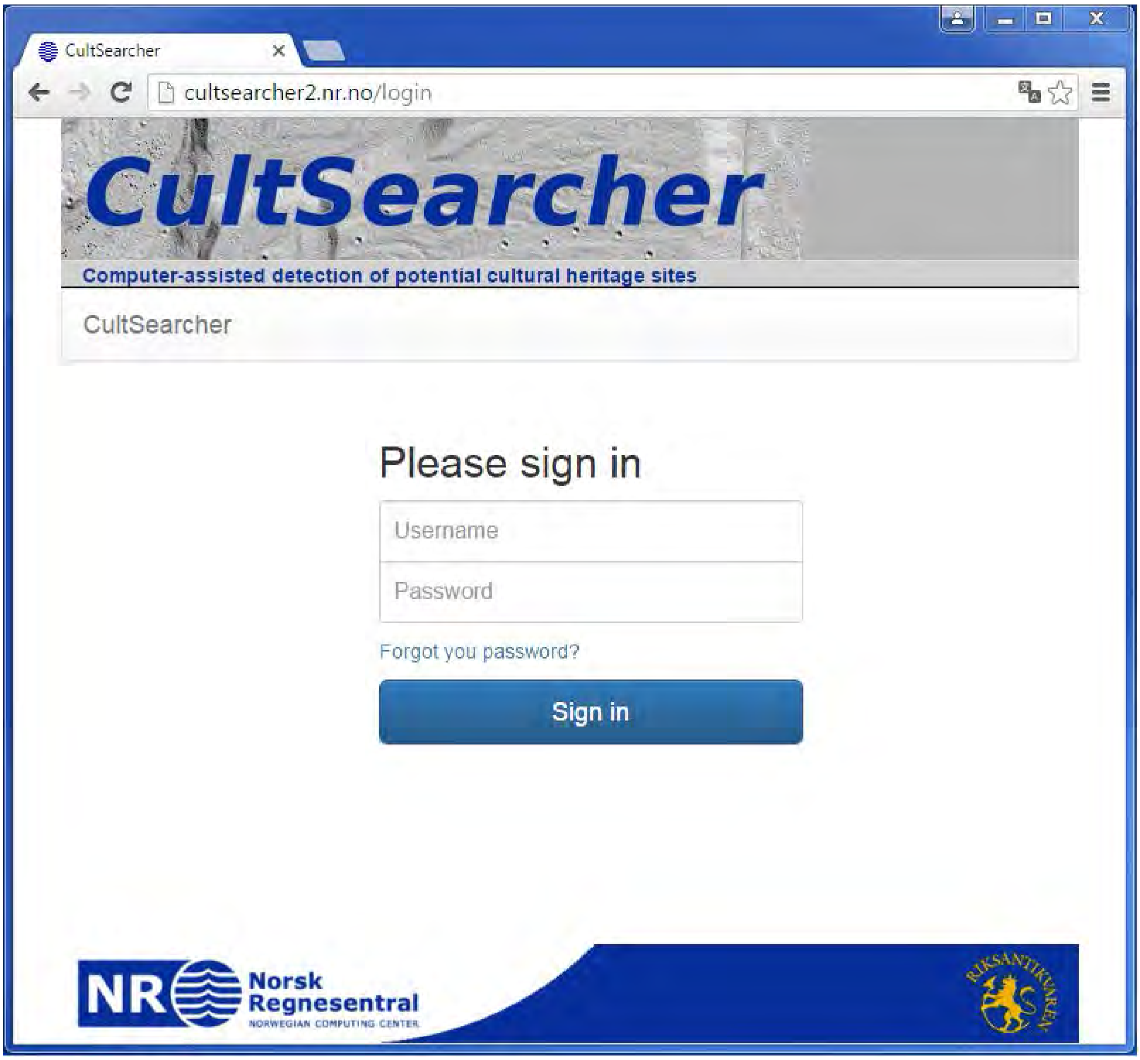


Figure 18. Pilot portal login.

5.2.2 Detailed example

After successful login, the user may select ‘datasets’ in the menu bar. If there are no uploaded datasets yet, the portal may look like Figure 19. The user may then select ‘new dataset’ (green button in Figure 19).

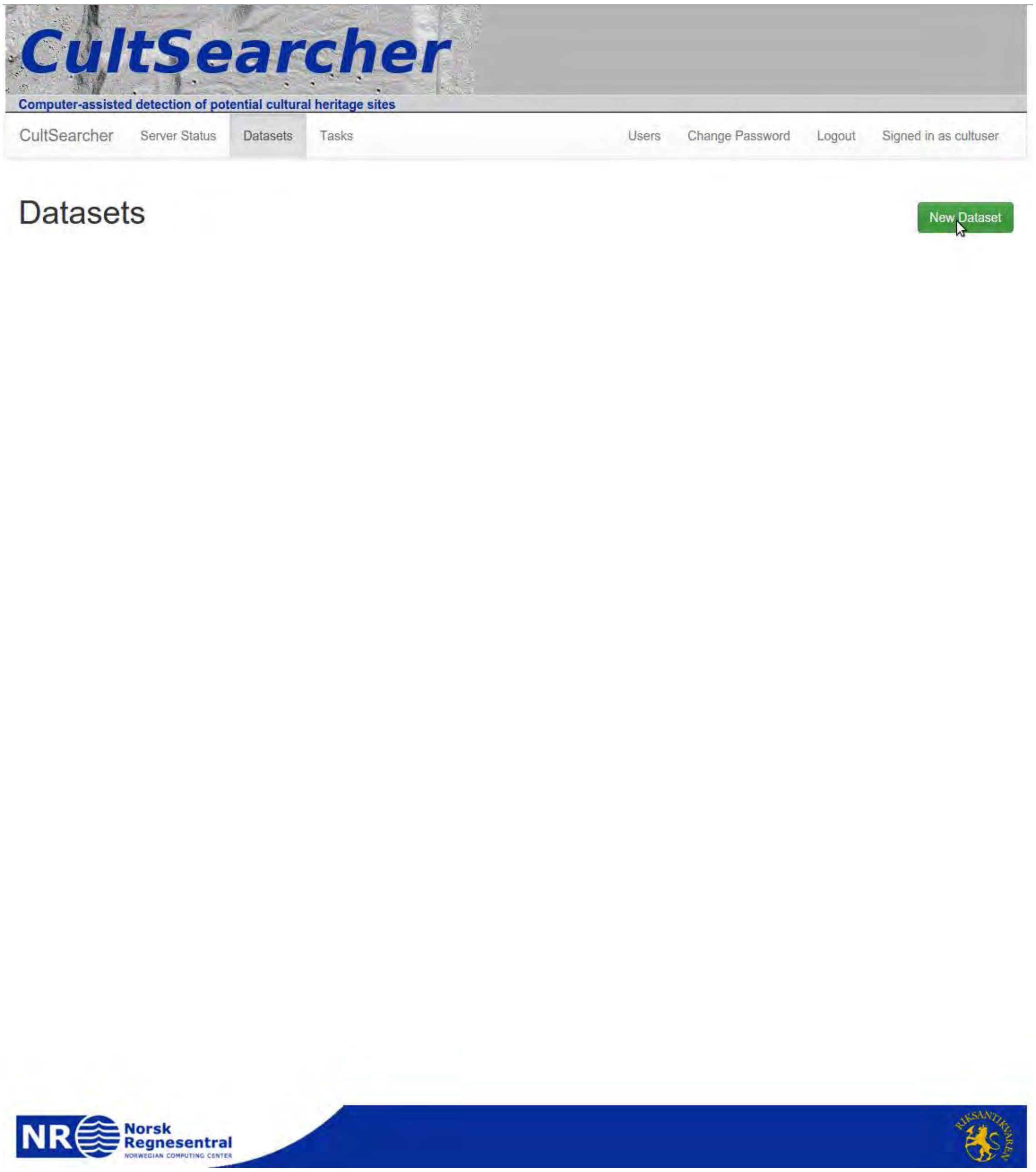


Figure 19. The CultSearcher portal, with no datasets uploaded yet for the current user.

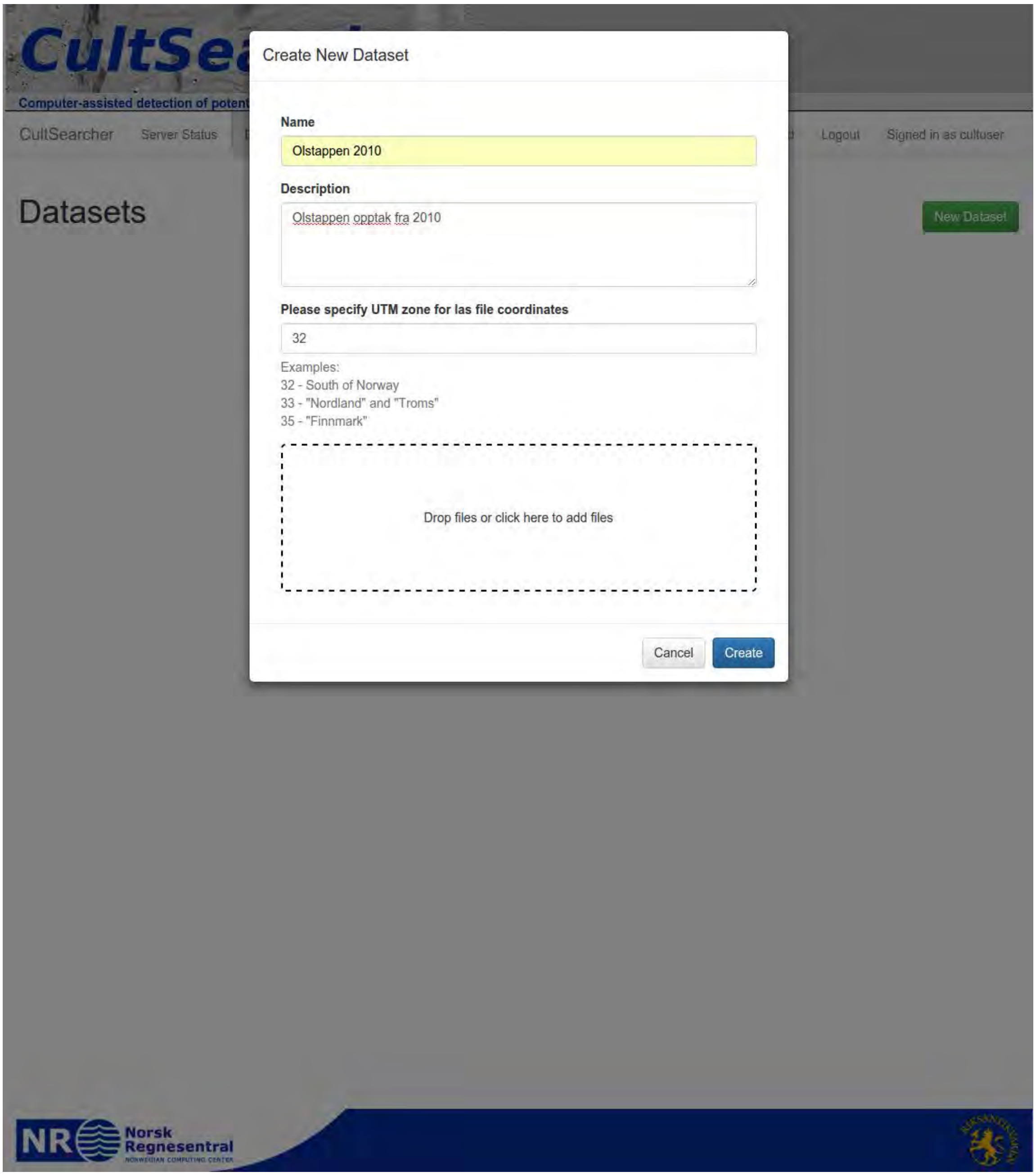


Figure 20. Dialogue for creating a new dataset.

A dialogue appears (Figure 20), in which the user may specify the name of the dataset, a description, and the UTM zone that the ALS data appears in. A number of laz or las files may also be specified. Once all this information is provided, the user may select 'create' (blue button in Figure 20).

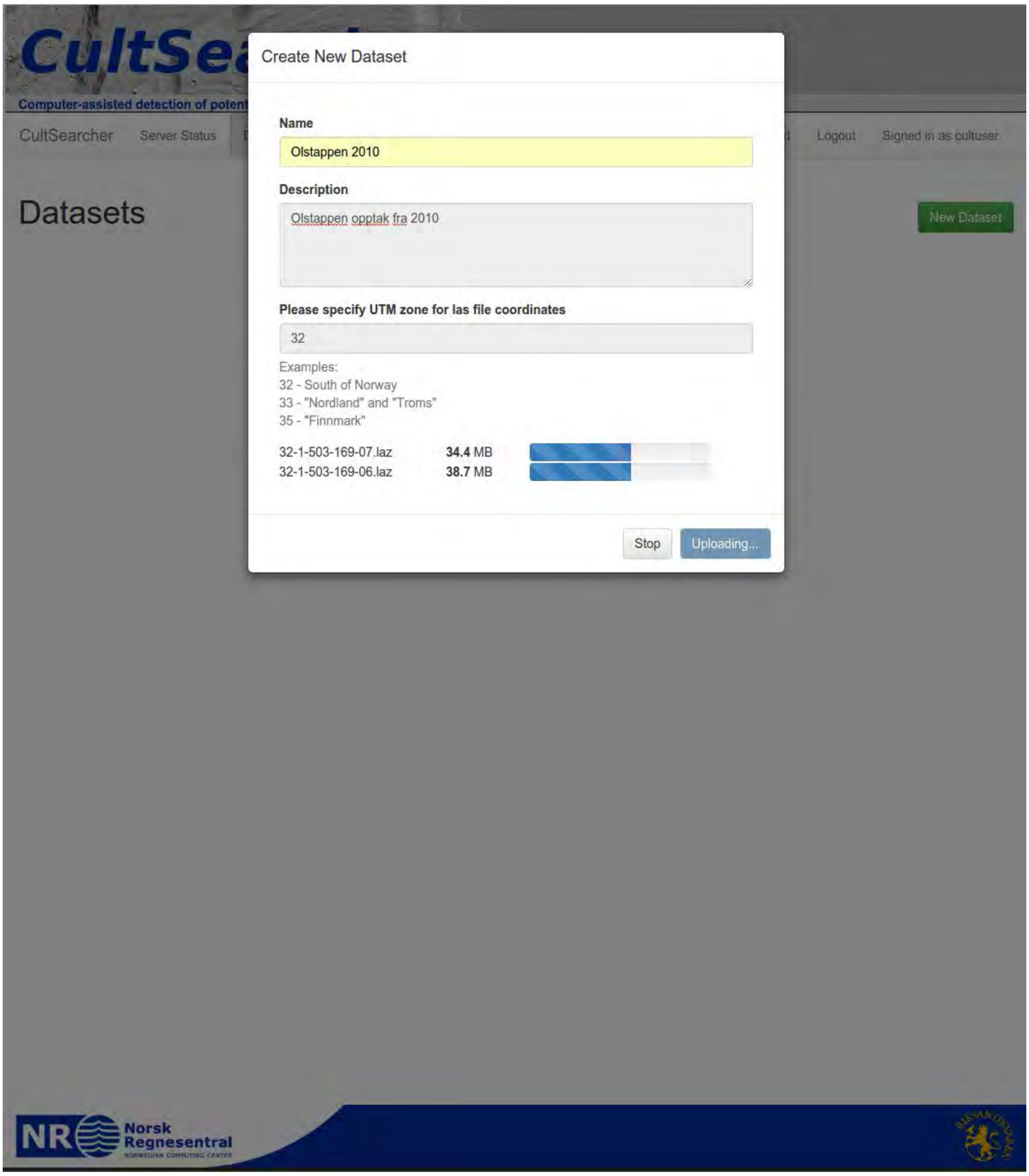


Figure 21. Uploading of ALS data into the pilot portal.

Then, the selected files are uploaded to the web server (Figure 21). In this small example, only two laz files were selected. However, many ALS datasets contain hundreds of files.

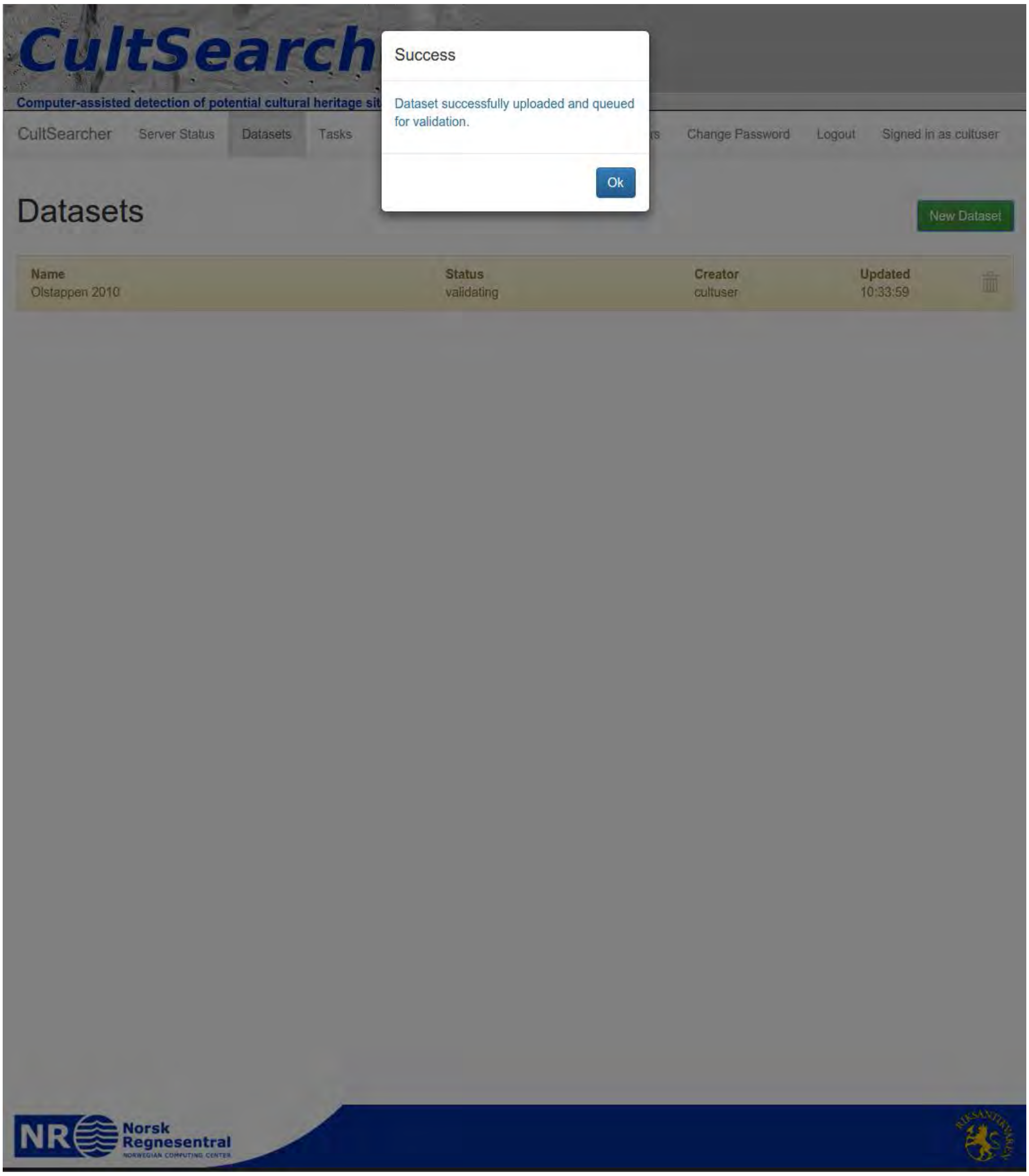


Figure 22. A dialogue informs that the dataset was uploaded.

When the ALS data has been successfully uploaded, a small informative dialogue appears (Figure 22). Click 'OK' to proceed.

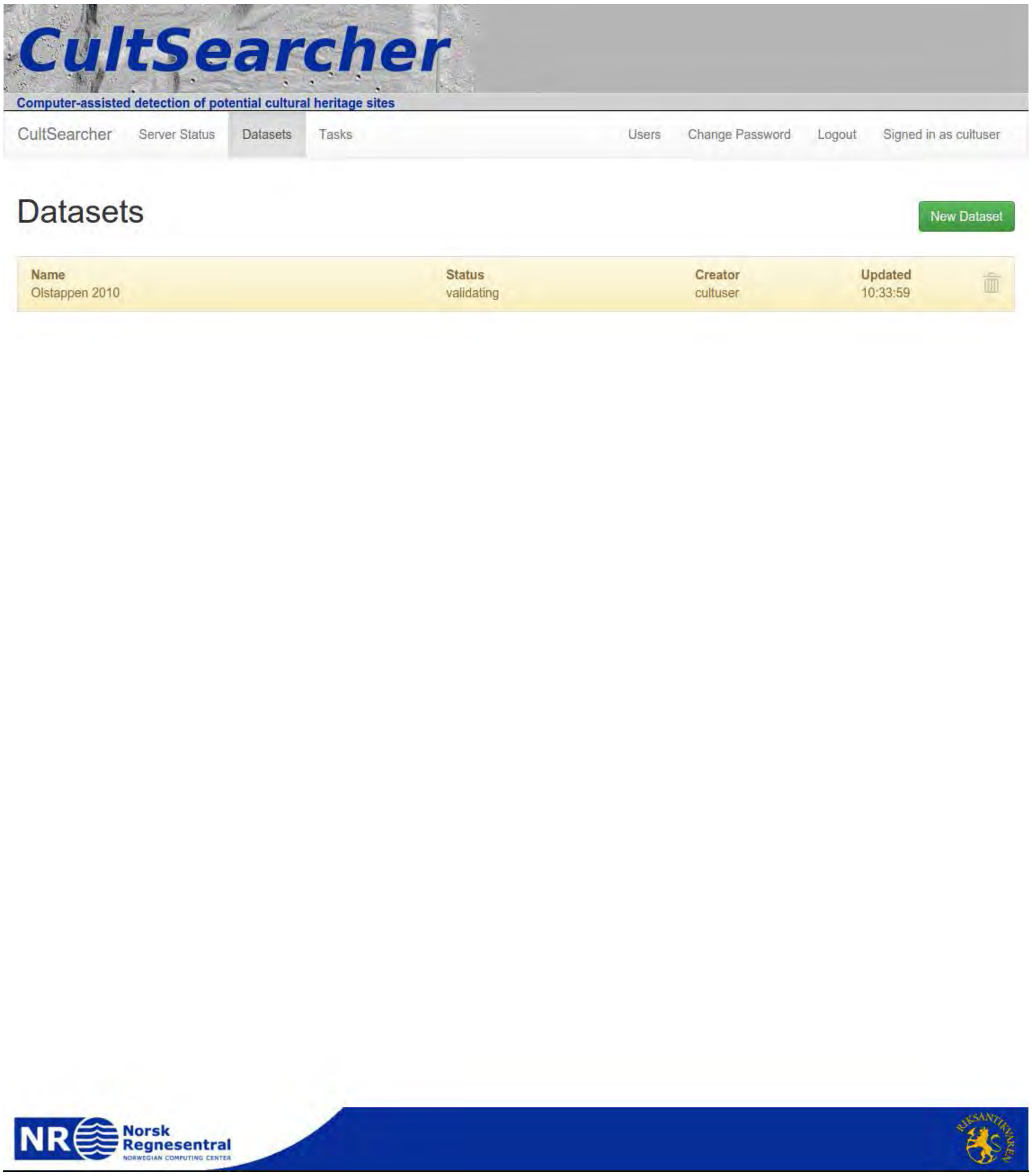


Figure 23. The uploaded ALS data is being validated by the server.

After a successful upload of ALS data, the server runs a validation process (Figure 23). This is a simple test to determine if the uploaded files were ALS data in the LAS file format, and that it was possible to extract a bounding rectangle for use in overview maps.

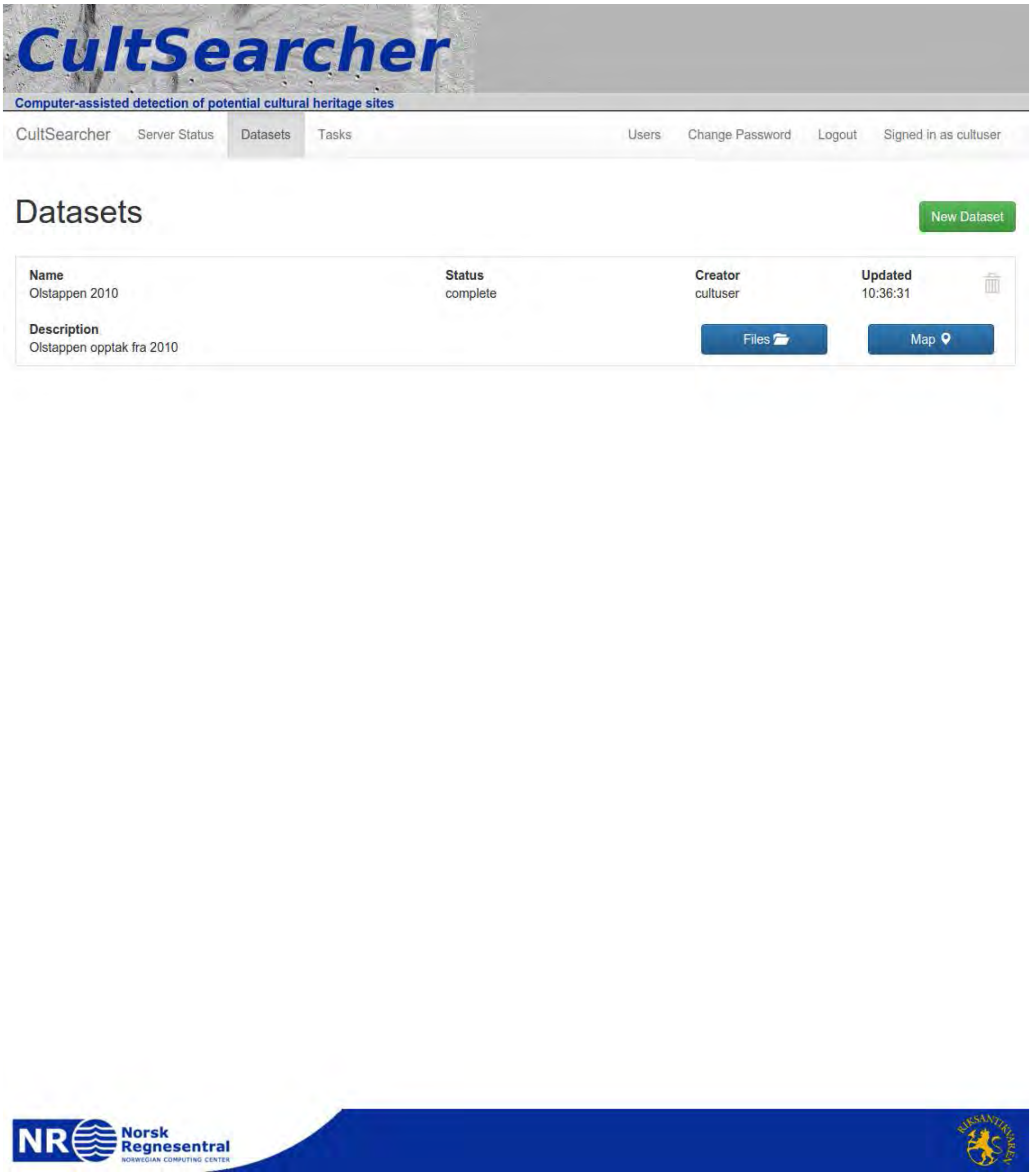


Figure 24. After validation of a dataset.

After successful validation of the dataset, the user may inspect the list of files (blue button labeled 'files' in Figure 24), in which case a list of files appears in a dialogue (Figure 25). The user may also want to see the file extents in an overview map (blue button labeled 'map' in Figure 25), in which case a pop-up window with an overview map appears (Figure 26).

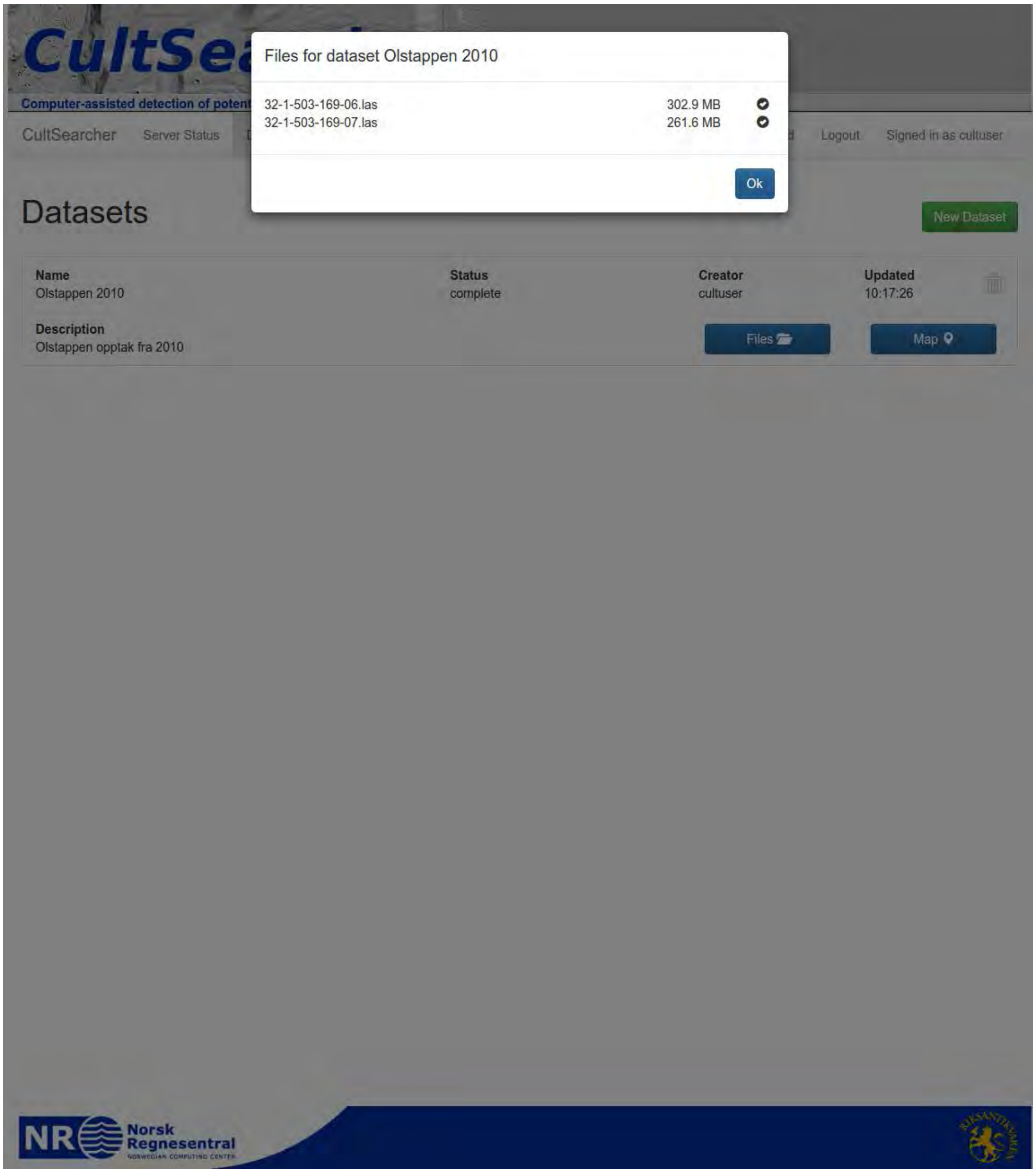


Figure 25. Dialogue with the list of files for a dataset.

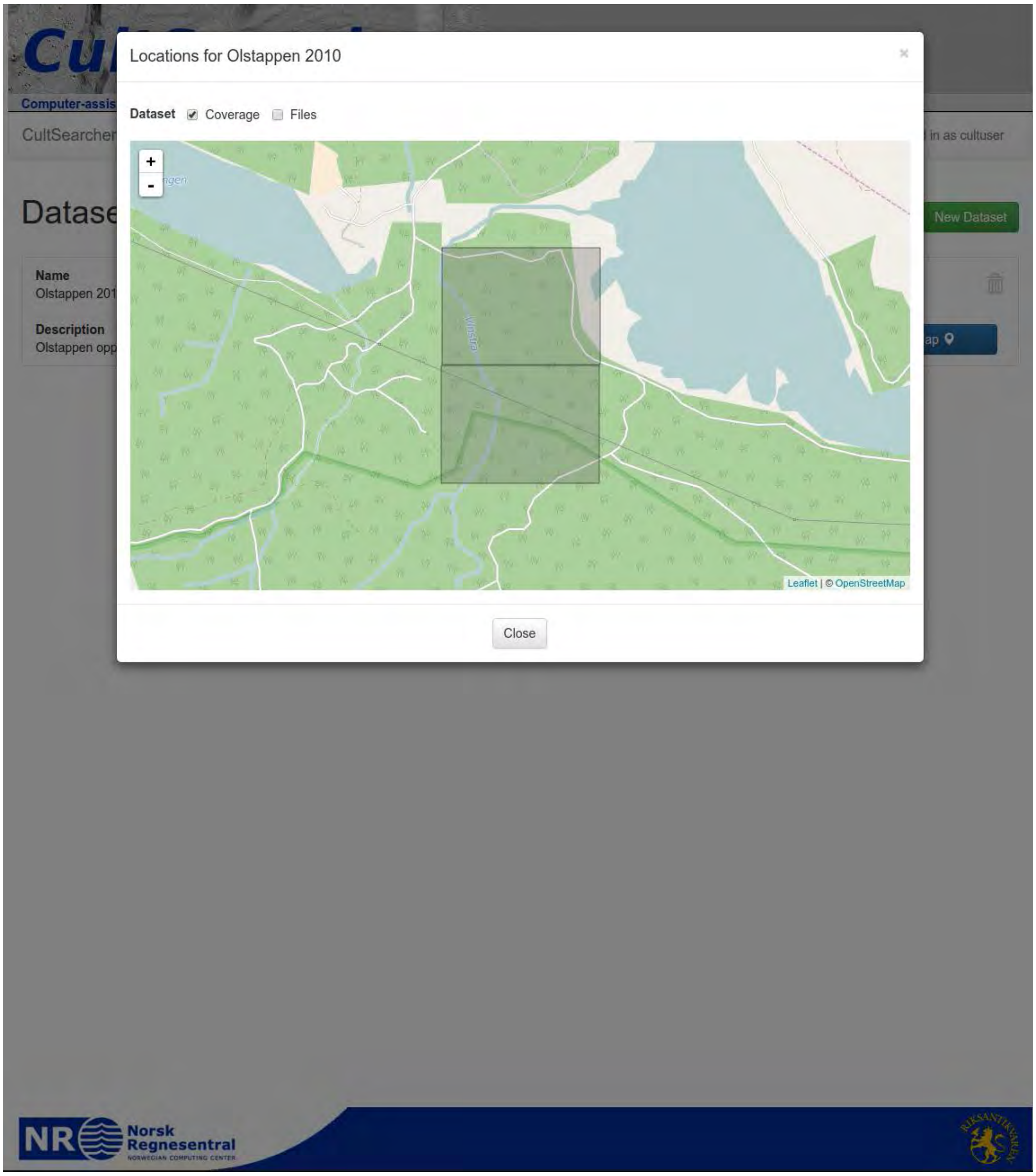


Figure 26. Overview map.

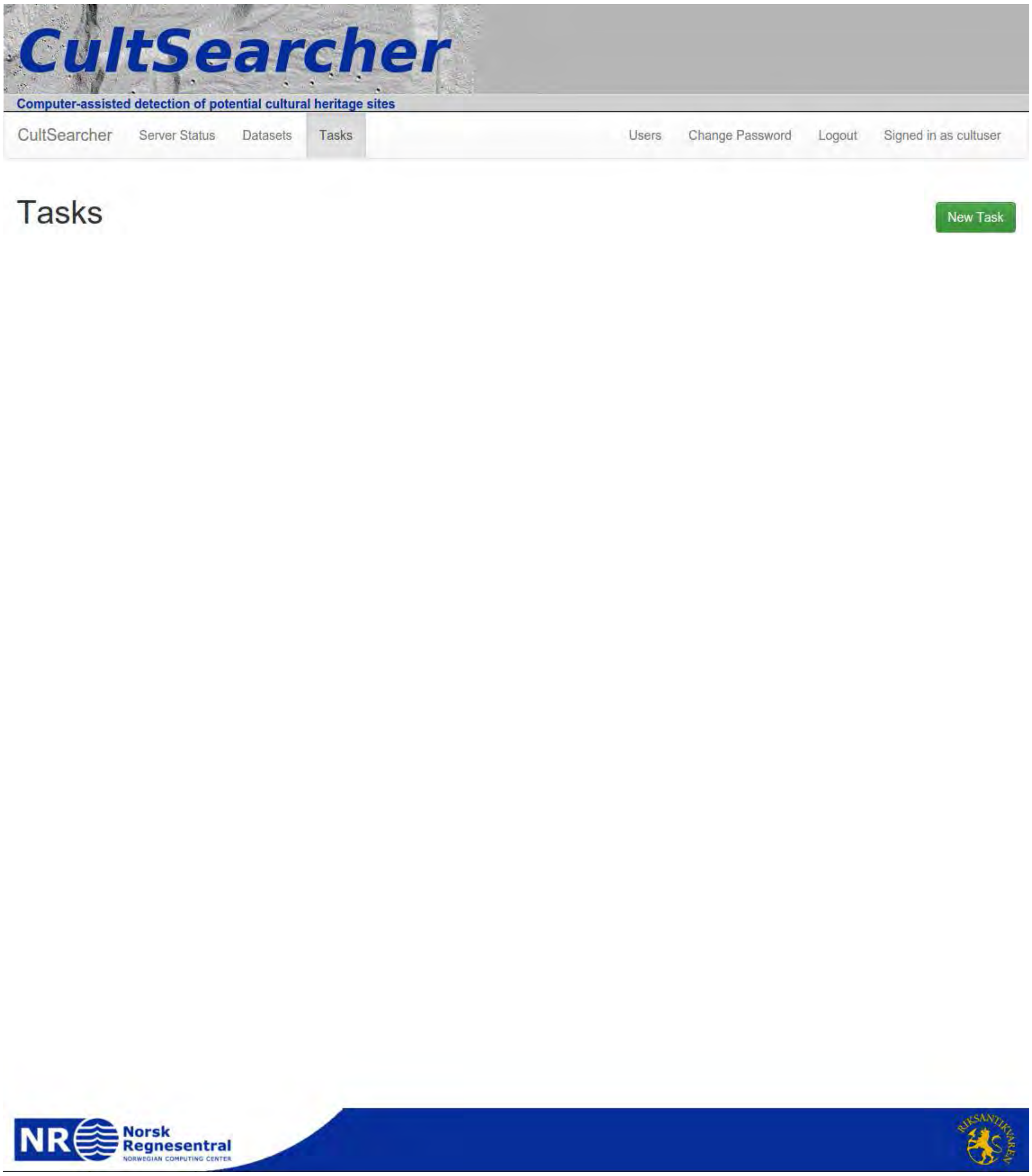


Figure 27. An empty task list.

In order to start the automatic detection method, the user must select ‘tasks’ in the menu bar. The task list appears, which may be empty if no previous tasks have been run (Figure 27). Select ‘new task’ (green button in Figure 27). A dialogue to create a new task appears (Figure 28).

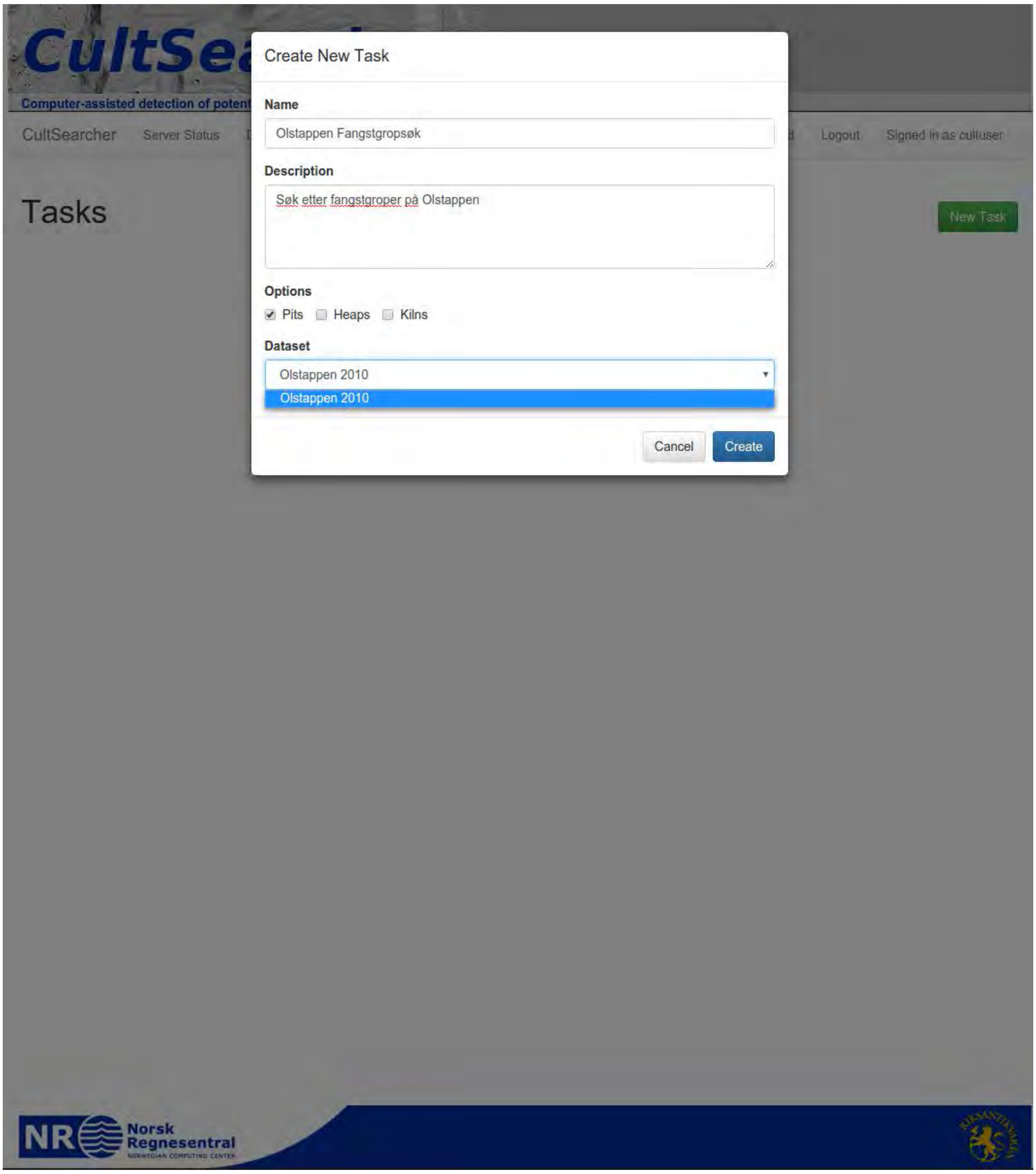


Figure 28. Dialogue for creating a new task.

The user first specifies a task name and a description. These are only informative text strings so that the user may recognize the task at a later stage. Then the user must specify what exactly the task will do: if pits and/or heaps are to be detected, and on which dataset to run.

Although there is an option to detect kilns, there is no automatic method yet that supports this option. Instead, kilns may be indirectly detected by a combination of pit detection and heap detection. But many kilns are also missed by this strategy.

As a final step in this dialogue, the user selects ‘create’ (blue button in Figure 28).

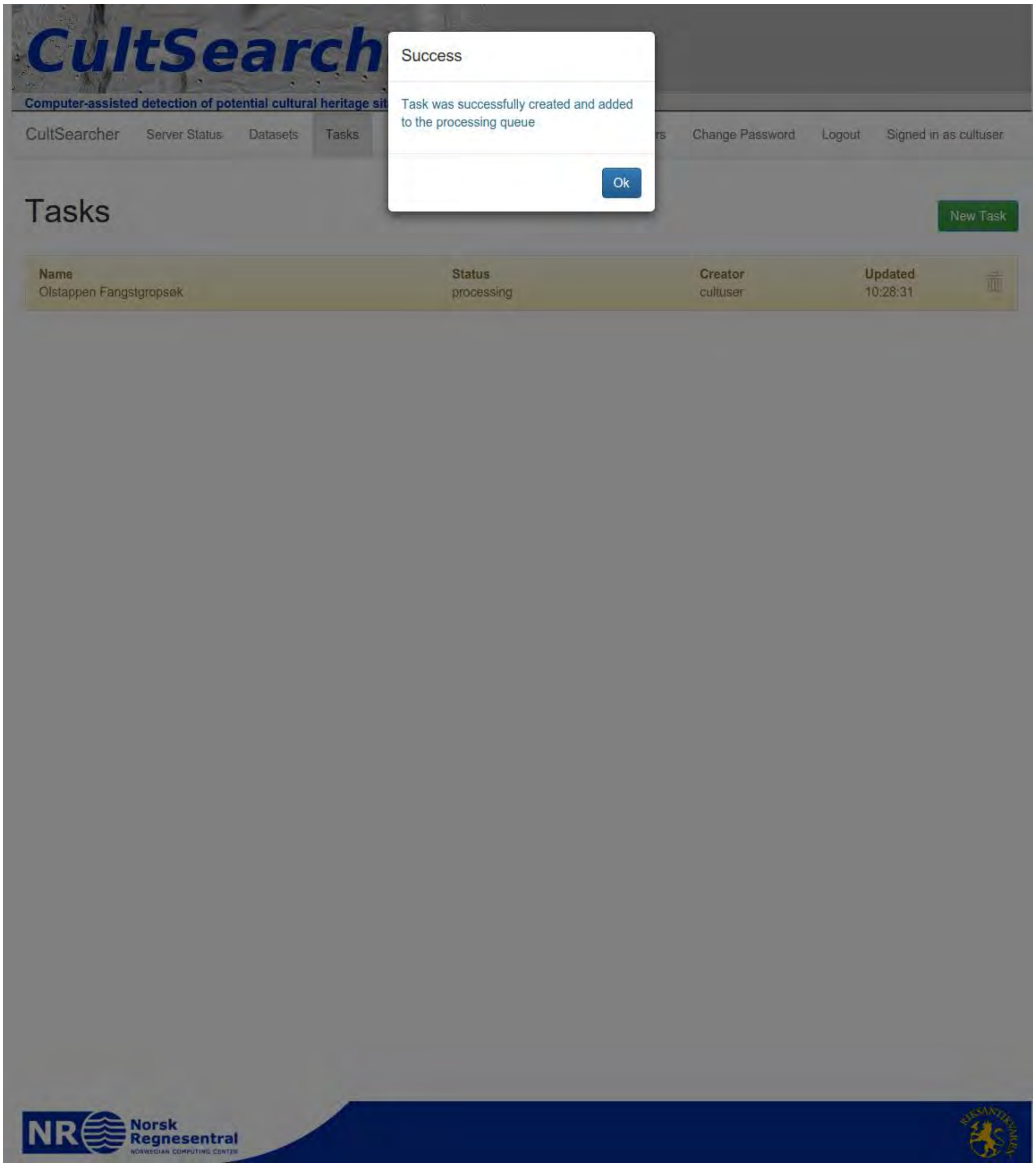


Figure 29. A small dialogue informs that the task was successfully created.

Then, if the information provided is complete, a small dialogue informs that the task was created (Figure 29).

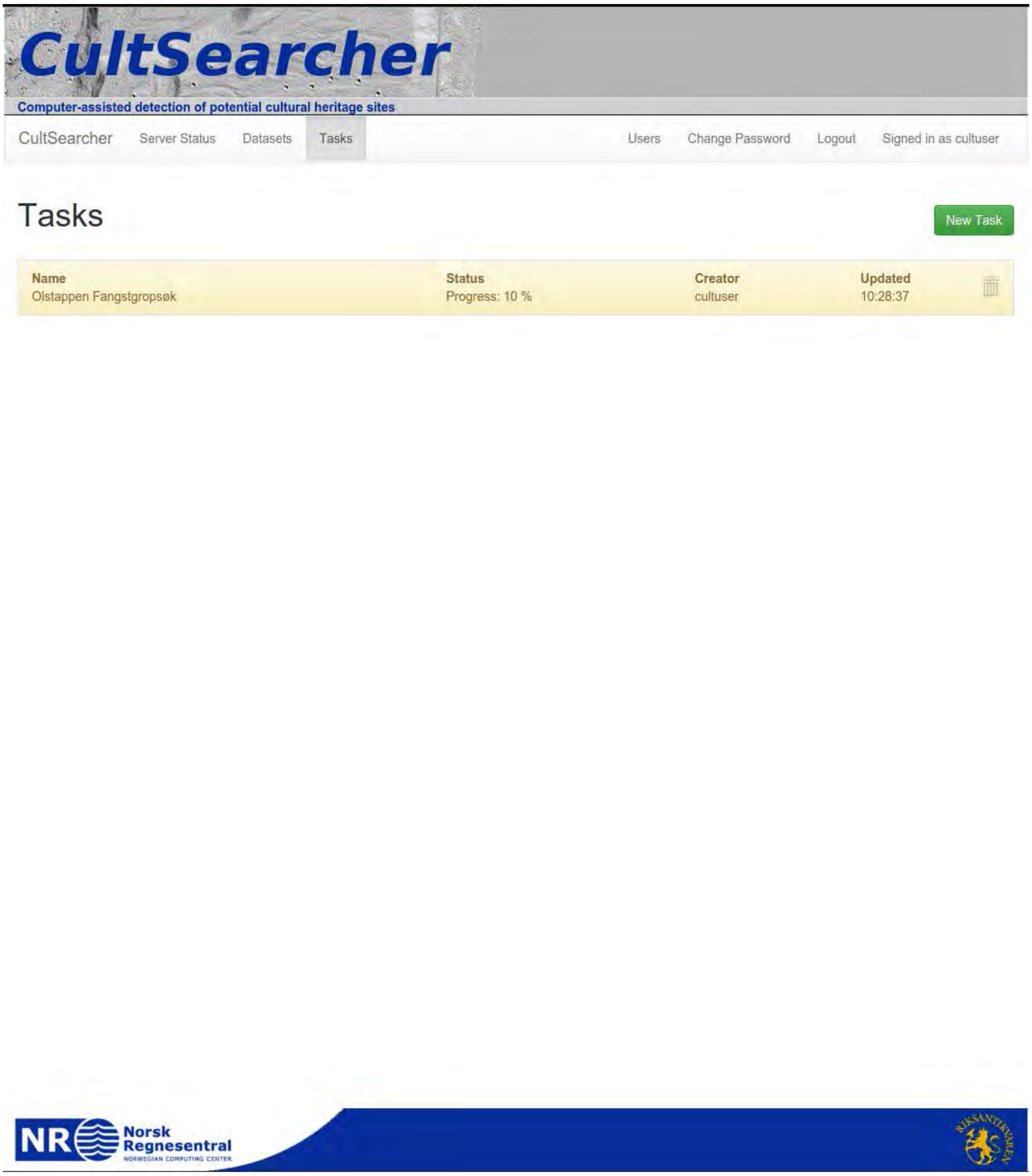


Figure 30. Task list with processing progress.

The task list now has one item (Figure 29). Unless there are other ongoing tasks, either for this user or other users, the new task will start immediately.

Figure 31. Server status page.

The user may select ‘server status’ in the menu bar, to view details on the current load on the server (Figure 31).

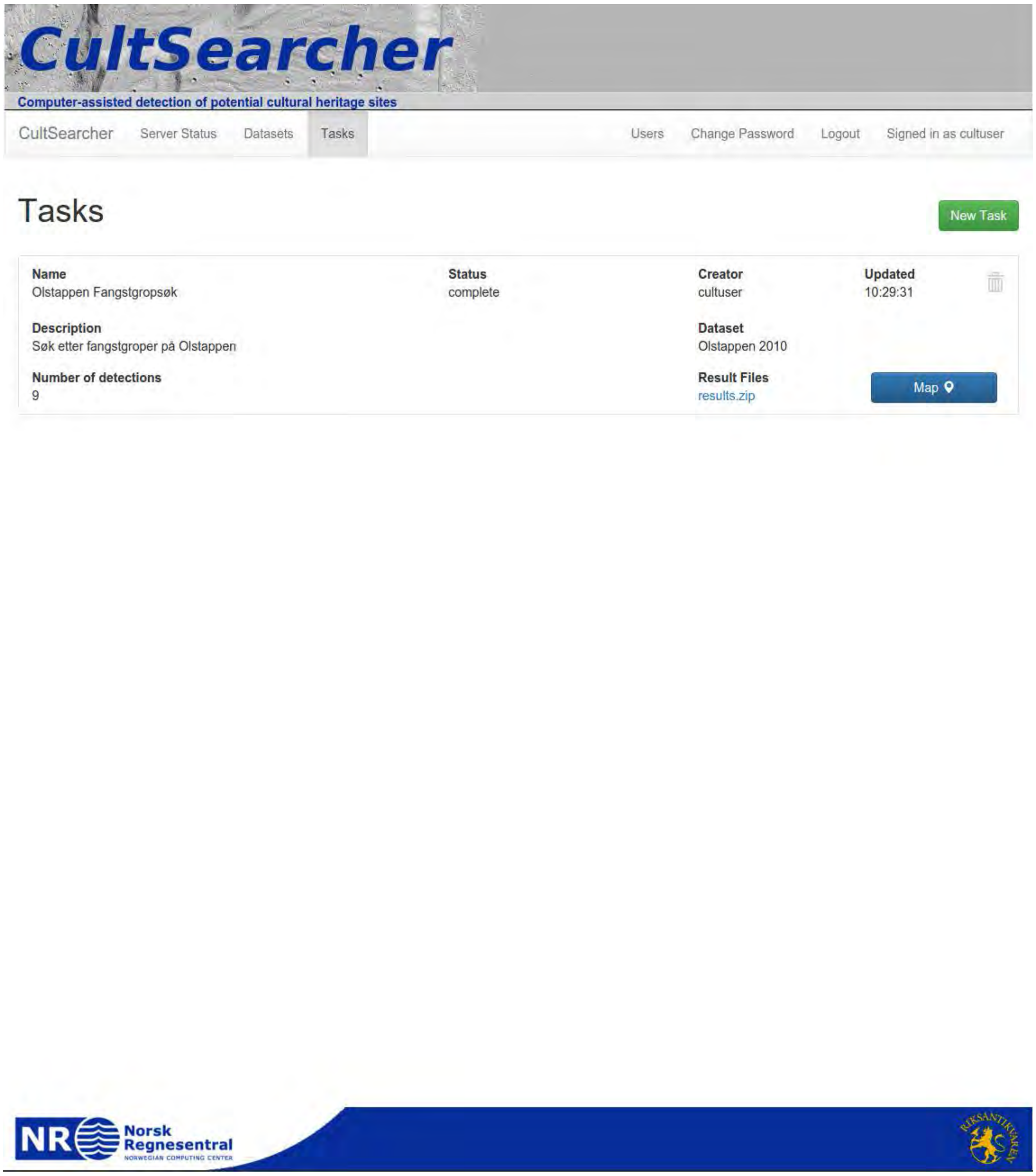
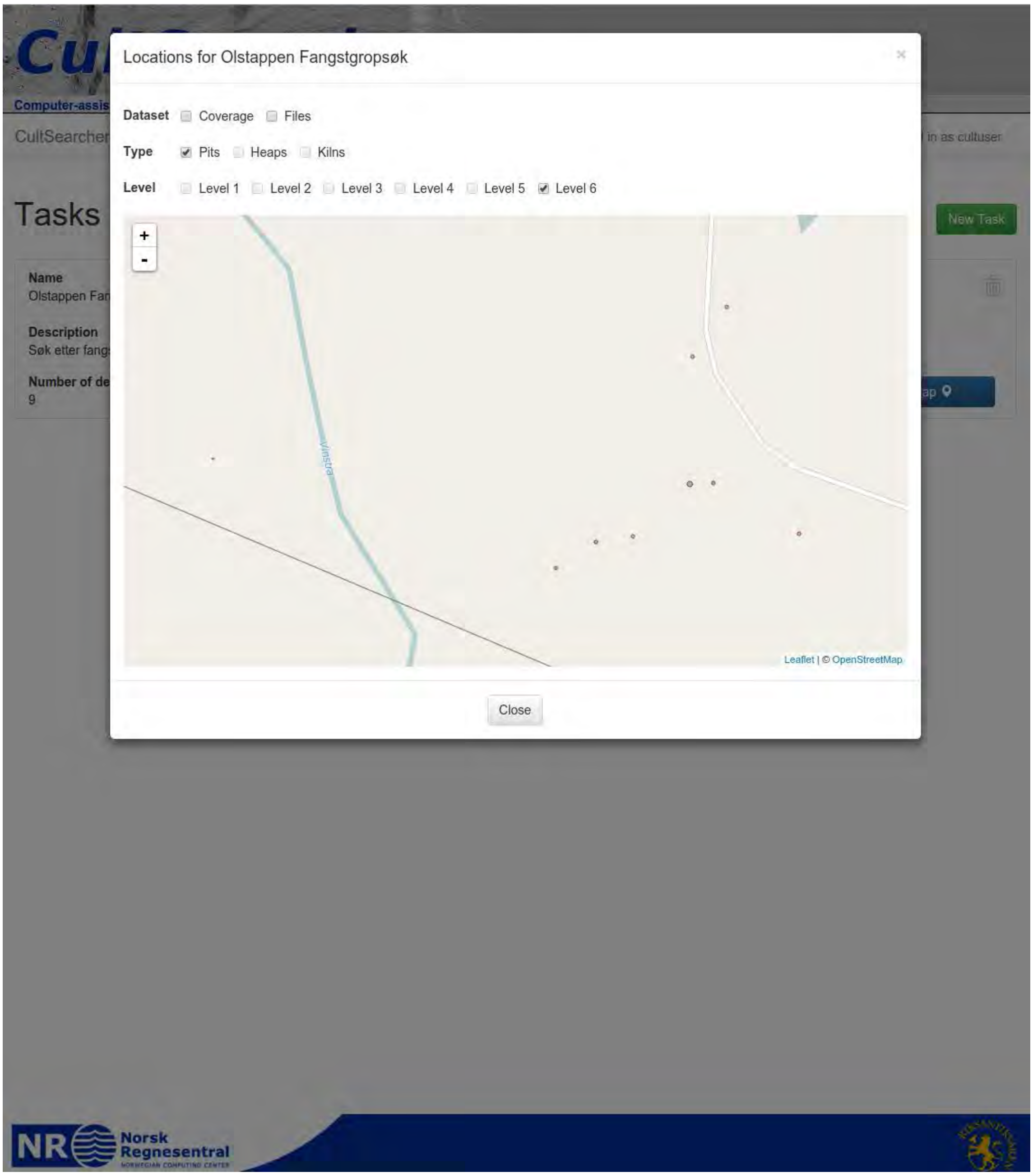


Figure 32. The task list after the completion of a task.

When a task has been completed, the number of detections is indicated, and a download link ‘results.zip’ is provided (Figure 32). The download link points to a compressed file containing ESRI Shape files of the automatic detections, with one layer for each confidence level 1-5.

The user may view the detections in a map (Figure 33) by selecting ‘map’ (blue button in Figure 32).

Figure 33. The automatic detections may be viewed in a map. This map is zoomed in on one of the pit detections.


Locations for Olstappen Fangstgropsøk
Dataset
Coverage
Files
Type
Pits
Heaps
Kilns
Level
Level 1
Level 2
Level 3
Level 4
Level 5
Level 6
Leaflet | © OpenStreetMap
Close
Tasks
Name
Description
New Task
Norsk Regnesentral

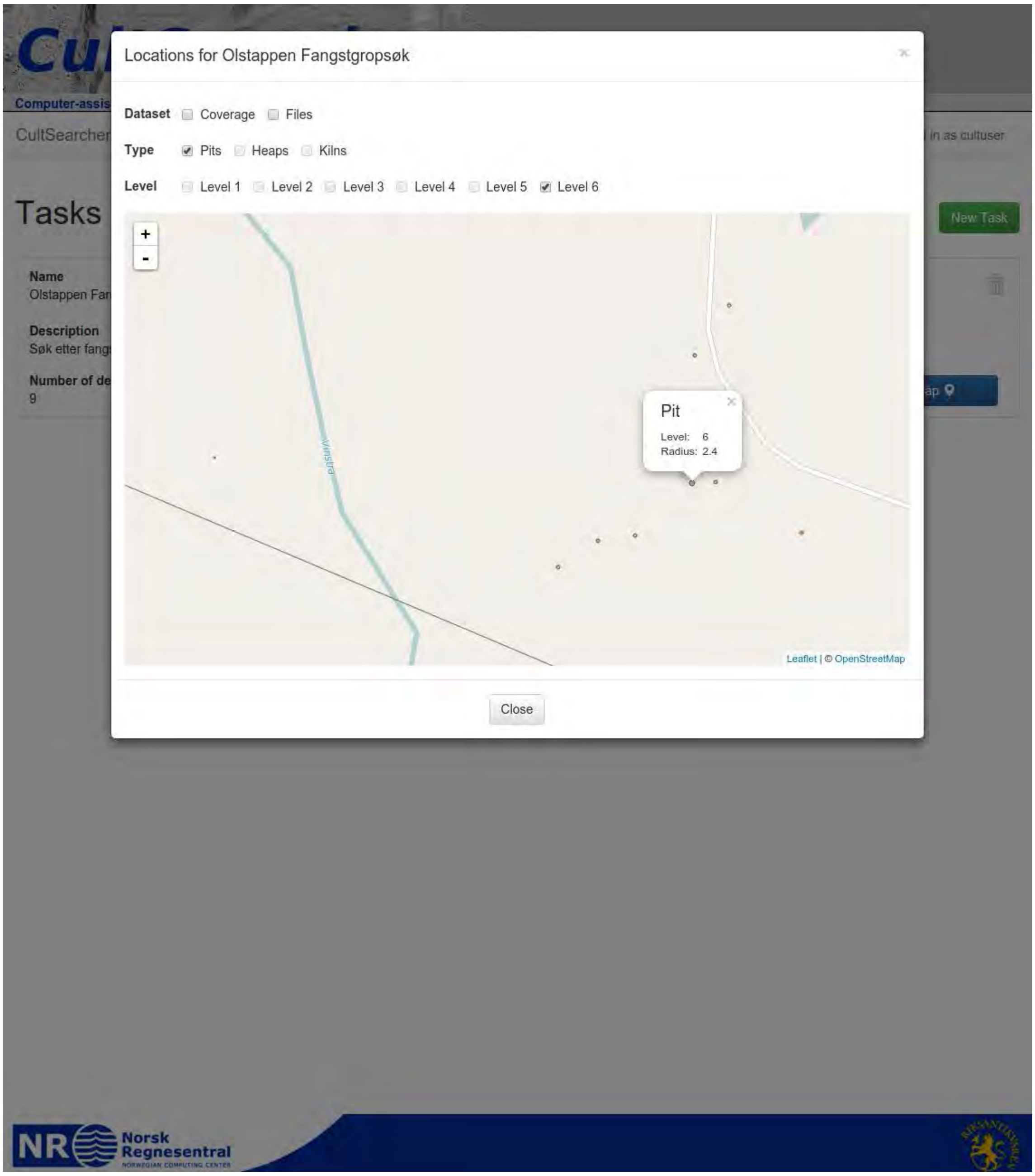


Figure 34. All nine pit detections in the small example from Olstappen.

By zooming out (by repeated use of the '-' button), all nine detections in the small example may be seen. By hovering over a detection, the type (pit or heap), confidence level and radius are viewed (Figure 34).

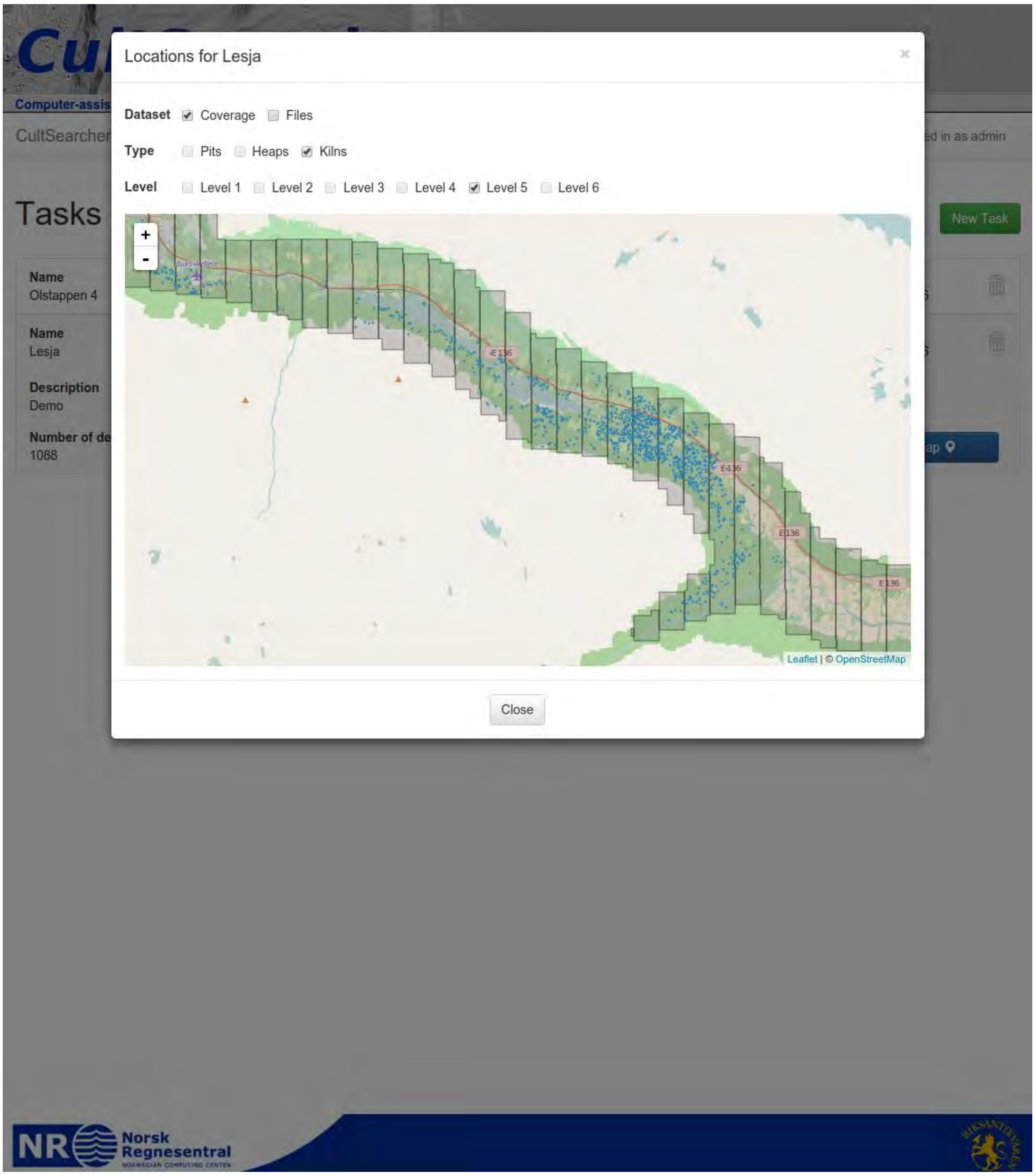


Figure 35. Charcoal kilns at Lesja. These have been verified by archaeologists. This area is about 31 km × 16 km.

To demonstrate the possibilities of the portal, a manually verified set of charcoal kilns has been uploaded (Figure 35). By zooming in (Figure 36, Figure 37), individual kilns may be inspected (Figure 37).

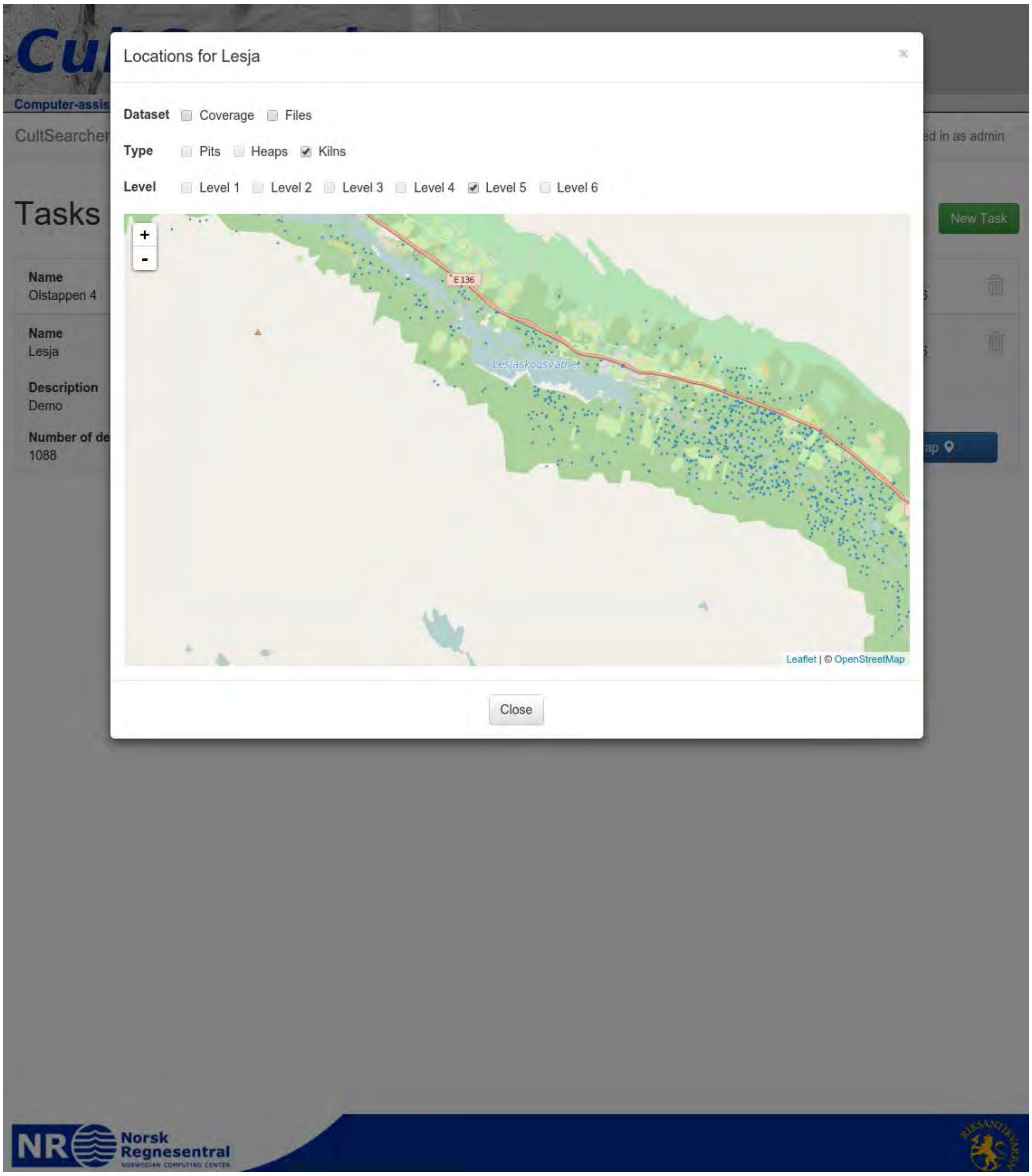


Figure 36. Some of the charcoal kilns at Lesja. This area is about 15 km × 8 km.

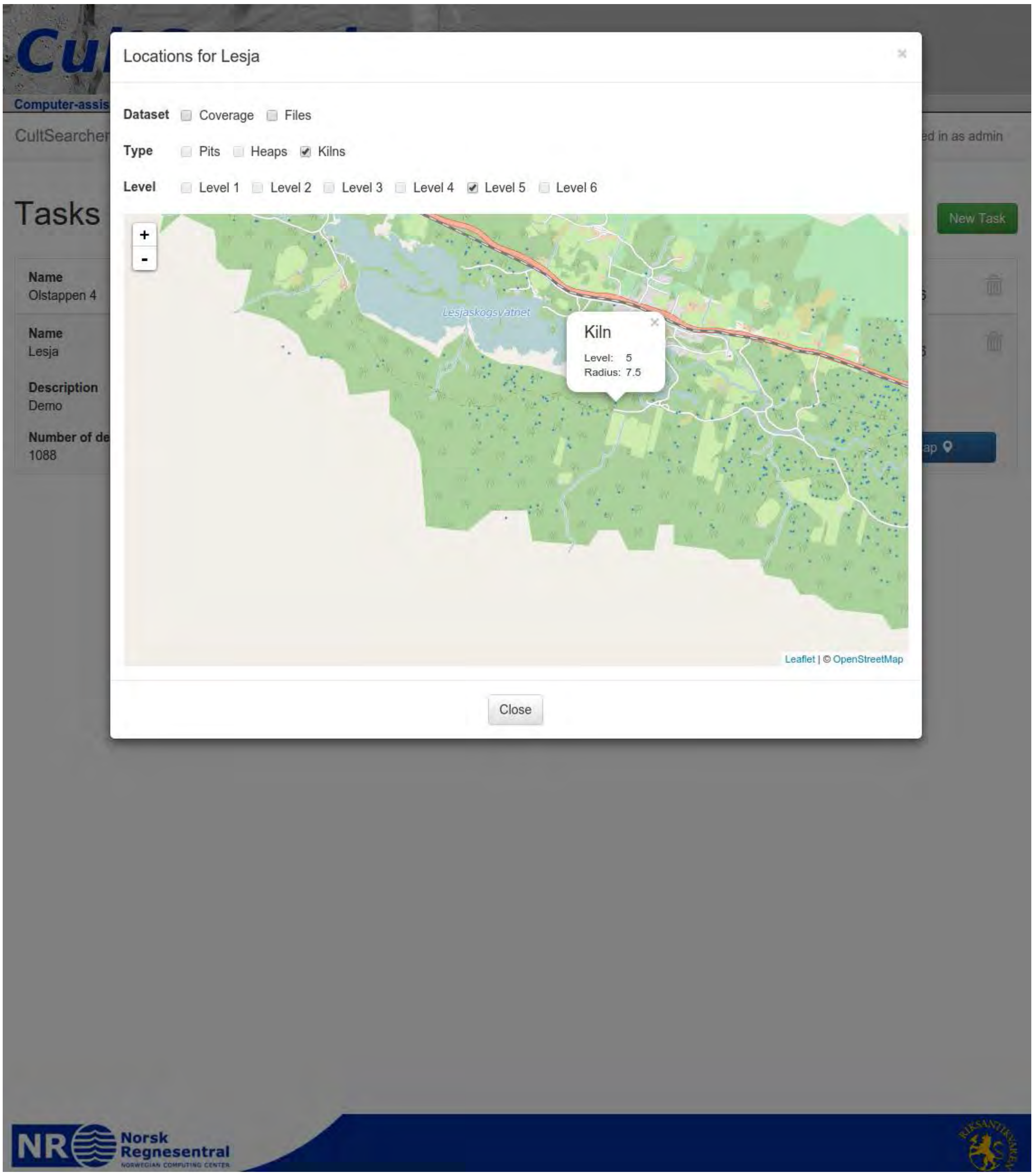


Figure 37. Inspecting one of the charcoal kilns at Lesja. This map covers about 7 km × 4 km..

5.3 Future directions for the pilot portal

A long-term goal is that the automatic detection methods be part of the national Norwegian infrastructure for digital maps (Norge Digitalt), so that archaeologists would not need to upload bulky ALS data to a standalone server, nor start the processing. Rather, there would be search and browse functionality to locate ALS datasets and associated automatic detections. On the rare event that an ALS dataset is available, but no automatic detection methods have been run yet, there could be an option to flag a dataset as 'high priority' for automatic detection.

However, the purpose of the pilot portal is to provide a short-term solution to the need for doing semi-automatic detection of cultural heritage structures.

Some possible improvements of the pilot portal have been identified:

1. Replace the current background map with hillshade images, and possibly other DTM visualizations, so that archaeologists may better understand which automatic detections may be true archaeological structures versus false. As part of the solution it may be necessary to pre-compute the hillshade and other DTM visualizations at several resolutions to allow for fast map navigation.

2. Automatic detection of kiln-like structures is currently not supported. Functionality for kiln detection is currently being developed.

3. Thorough stress-testing needs to be undertaken in order to identify possible problems with several concurrent users and large ALS datasets.

4. The current implementation relies on using ENVI licenses, which are expensive. ENVI is an extension to IDL. It is possible to re-write parts of the code to eliminate the use of ENVI and only use IDL. One must then use the Geotiff image file format instead of ENVI's proprietary image file format. This has the benefit that the Geotiff image file format is widely accepted, including the use in background maps (see item 1 above).

5.4 Acknowledgement

This research was funded by the Directorate for Cultural Heritage in Norway (Riksantikvaren).

6 Discussion and conclusions

The initial experiments with using deep learning in detection of charcoal kilns gave 85% correct classification of the true charcoal kilns. In addition, only 10% false positives were obtained. This is dramatically better than the results we have obtained using traditional pattern recognition for the detection of grave mounds and charcoal kilns.

The only previous example in this project in which traditional pattern recognition gave similarly good results was detection of pitfall traps at Lake Olstappen i Nord-Fron municipality, Oppland County. In that dataset, the pitfall traps stand out very well from the surrounding terrain, so it was possible to hand-craft a method that was able to detect more than 90% of the pitfall traps. However, the number of false positives was substantially higher than 10%, and very dependent on the terrain morphology.

The major success of deep learning in the initial experiment suggests that similar methods should be developed for grave mounds and archaeological pits (pitfall traps, charcoal pits) and possibly other structures that the project has yet not addressed. These methods should be made available in the pilot portal, and, in the future, in a national infrastructure for airborne laser scanning data.

Although an automatic method makes some mistakes, it may still be a major contributor by making detailed archaeological mapping less time consuming, and at the same time, more accurate and complete, compared to pure visual inspection of the ALS data. However, this is only true if the number of false positives is relatively low, and the correct classification rate is at least quite high. Given the initial results from using deep learning, this now seems realistic.

Automatic detection methods help to reduce the effects of fluctuations of human concentration in doing repeated tasks. Indeed, it is easier to spot one missing charcoal kiln among nine automatically detected kilns, than to avoid overlooking one out of ten kilns when none are flagged.

In conclusion, project funding for one more year is vital to implement deep learning-based methods in the pilot portal. This will turn the pilot portal into a workhorse for semi-automatic detection of archaeological structures from airborne laser scanning data.

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Appendix A. Photo documentation of charcoal kilns at Lesja

On 1 November 2015, 70 charcoal kilns were visited and photographed by NR (Table 2, Figure 38). They had already been visited in 2014 by Oppland County. The GPS positions, characteristics and comments in Table 2 are from the 2014 visit.

Table 2. 70 charcoal kilns at Lesja Ironworks. The characteristics are described in Table 3.

	Photo id		GPS position		Corrected position in DTM			Chraracteristics					
Id	from	to	east	north	east	north	rad	Di	Pl	M	PO	DK	Comment (in Norwegian)
1	6114	6122	478 450,8	6 894 672,0	478 451,0	6 894 672,0	6,0	2	0	2	0	0	Bekreftet som kullmile
2	6123	6129	478 509,0	6 894 761,3	478 509,0	6 894 761,7	8,3	0	1	1	0	0	Bekreftet som kullmile
3	6128	6144	478 545,9	6 894 731,8	478 545,0	6 894 732,0	7,0	0	1	0	0	0	Groper rundt den
4	6145	6149	478 596,5	6 894 763,7	478 595,9	6 894 765,1	7,0	1	1	2	0	1	Doble kullmile. Muligens voll rundt
5	6150	6153	478 619,2	6 894 807,5	478 619,5	6 894 807,1	6,7	1	0	0	0	0	Svak grøft□
6	6154	6158	478 632,7	6 894 854,7	478 633,0	6 894 854,7	7,2	2	0	2	0	0	Bekreftet som kullmile
7	6159	6170	478 756,7	6 894 806,8	478 757,3	6 894 807,5	6,9	0	1	2	0	0	Bekreftet som kullmile
8	6171	6175	478 732,4	6 894 756,9				0	1	1	0	0	Registrert i felt som e17- NØ for E16
9	6176	6183	478 697,0	6 894 744,0	478 696,9	6 894 744,1	6,1	1	0	0	0	0	Bekreftet som kullmile
10	6184	6188	478 684,0	6 894 757,4	478 683,5	6 894 757,9	8,4	1	1	2	0	0	Bekreftet som kullmile
11	6189	6199	478 797,2	6 894 717,8	478 797,0	6 894 719,1	8,8	2	0	1	0	0	grøft rundt
12	6200	6208	478 816,9	6 894 686,8	478 814,9	6 894 687,7	7,0	0	1	0	0	0	Bekreftet som kullmile
13	6209	6213	478 816,7	6 894 707,3	478 817,0	6 894 708,1	6,1	0	1	0	0	0	Anomali 58
14	6214	6218	478 747,5	6 894 569,7	478 745,9	6 894 570,1	7,6	1	1	1	0	0	Bekreftet som kullmile
15	6219	6224	478 757,0	6 894 538,9	478 756,9	6 894 540,1	6,8	0	1	1	0	0	Bekreftet som kullmile
16	6225	6227	478 682,4	6 894 573,6	478 681,9	6 894 572,5	8,6	0	1	1	0	1	Dobbel kullmile
17	6228	6235	478 694,2	6 894 632,1	478 693,5	6 894 632,1	4,9	0	1	0	0	0	Anomali 56- Groper rundt. Ingen grøft
18	6236	6238	478 574,0	6 894 573,2	478 573,0	6 894 573,5	7,0	2	0	1	0	0	Svak grøft
19	6239	6243	478 560,2	6 894 613,9				1	1	0	0	0	Anomali 57- NØ for tuft E20
20	6244	6248	478 529,3	6 894 583,1	478 529,5	6 894 582,5	8,0	2	0	0	0	0	Svak grøft
21	6249	6253	478 391,8	6 894 520,6	478 392,1	6 894 520,5	6,9	1	1	0	0	0	Groper rundt. Antydning til grøft
22	6254	6262	478 365,4	6 894 517,7	478 364,0	6 894 518,7	6,9	0	1	1	0	0	Groper rundt. Ingen grøft
23	6263	6267	478 292,2	6 894 583,7	478 292,3	6 894 583,1	9,4	2	1	1	0	0	Små groper rundt
24	6268	6270	478 279,5	6 894 597,1				2	0	0	0	0	Registrert i felt som e25- grøft rundt
25	6271	6274	478 231,9	6 894 551,1	478 231,3	6 894 550,7	7,3	0	1	0	0	0	Groper rundt. Traktor spor ved den
26	6275	6279	478 224,9	6 894 508,2				1	0	0	0	0	Anomali 62
27	6280	6286	478 218,8	6 894 398,0	478 218,3	6 894 397,1	8,3	0	1	1	0	0	Bekreftet som kullmile
28	6287	6290	478 296,0	6 894 372,8	478 296,0	6 894 374,1	7,5	1	1	1	0	0	Groper og grøft, men mest grøft
29	6291	6297	478 391,4	6 894 397,1	478 391,0	6 894 397,6	8,0	1	1	2	0	0	Mest groper
30	6298	6303	478 430,5	6 894 278,3	478 428,9	6 894 278,5	8,1	1	1	1	0	0	Groper og grøft
31	6304	6308	478 540,2	6 894 263,5	478 540,3	6 894 265,5	6,8	2	1	0	0	0	grøft og groper
32	6309	6312	478 546,0	6 894 232,0	478 546,0	6 894 232,5	4,5	0	1	0	0	0	Anomali 14
33	6313	6315	478 290,4	6 894 308,6	478 289,0	6 894 309,0	7,0	2	0	2	0	0	Bekreftet som kullmile
34	6316	6325	478 108,7	6 894 352,0	478 107,5	6 894 350,7	6,0	0	1	0	0	0	Groper rundt den
35	6326	6337	478 093,9	6 894 323,4	478 094,5	6 894 322,7	8,8	1	1	0	0	0	Groper rundt den
36	6338	6338	478 057,9	6 894 301,8				1	0	1	0	0	Registrert i felt som e41
37	6339	6341	477 993,8	6 894 328,1	477 994,0	6 894 329,0	6,5	2	0	2	0	0	Kullmile med grøft. Markert forhøying
38	6342	6344	477 988,6	6 894 224,5	477 989,0	6 894 222,7	7,2	2	1	2	0	0	Groper og grøft, men mest grøft
39	6345	6347	477 985,1	6 894 170,7	477 984,5	6 894 171,1	7,7	2	1	2	0	0	Grunn grøft, men også groper
40	6348	6353	477 968,2	6 894 099,6	477 968,0	6 894 100,0	8,5	2	1	1	0	0	Mest grøft, men noen groper
41	6354	6360	477 990,9	6 894 096,9	477 990,3	6 894 096,1	8,5	0	1	0	0	0	Groper rundt
42	6361	6363	478 025,4	6 894 058,0	478 023,9	6 894 059,9	9,5	2	0	1	0	0	grøft rundt
43	6364	6369	478 007,9	6 894 045,5	478 013,3	6 894 046,9	6,3	0	1	0	0	0	Registrert i felt som e49
44	6370	6373	477 948,2	6 894 039,8	477 947,5	6 894 041,5	7,3	2	1	1	0	0	Bekreftet som kullmile
45	6374	6383	477 893,6	6 893 985,5	477 894,0	6 893 986,0	10,5	0	1	0	0	0	Større groper, ingen grøft
46	6384	6388	477 952,8	6 893 896,0				0	1	0	0	0	Registrert i felt som e51
47	6389	6392	478 006,3	6 893 892,7	478 007,6	6 893 897,1	9,2	0	1	0	0	0	Groper rundt
48	6393	6394	478 203,2	6 894 031,5	478 204,0	6 894 032,4	7,0	2	1	0	0	0	grøft rundt
49	6395	6395	478 158,3	6 894 081,4				0	1	1	0	0	Registrert i felt som e54
50	6399	6400	478 258,9	6 894 083,7	478 259,7	6 894 083,7	7,6	2	1	1	0	0	Lav forhøyning. grøft og grop, men mes grøft

	Photo id		GPS position		Corrected position in DTM			Chraracteristics					
Id	from	to	east	north	east	north	rad	Di	PI	M	PO	DK	Comment (in Norwegian)
51	6401	6404	478 275,2	6 894 090,1	478 275,2	6 894 090,8	7,6	2	1	2	0	0	Stor forhøyning. grøft og groper. Grop innenfor
52	6405	6406	478 295,8	6 894 092,3	478 295,9	6 894 091,7	6,9	2	1	2	0	0	Middels høy forhøyning. grøft rundt
53	6407	6413	478 310,3	6 893 999,4	478 310,9	6 893 998,1	8,5	1	1	2	0	0	grøft og groper, men mest groper. Den er noe skadet av skogsmaskiner
54	6414	6417	478 371,5	6 893 902,7	478 370,3	6 893 903,5	6,7	0	1	2	0	0	Stor forhøyning. Groper rundt
55	6418	6423	478 366,7	6 893 861,5	478 368,0	6 893 862,6	6,0	2	1	0	0	0	Groper og grøft rundt
56	6424	6426	478 425,3	6 893 889,7	478 424,5	6 893 890,1	3,2	1	1	1	1	0	grøft og groper. Veldig dyp grop i SV
57	6427	6430	478 489,4	6 893 837,2	478 490,1	6 893 837,1	9,0	2	1	2	0	0	Stor forhøyning. grøft og groper
58	6432	6433	478 586,8	6 893 883,0				1	0	0	0	0	Registrert i felt som e70. Ikke lett å se hva punktet markerer på DTM
59	6434	6434	478 583,5	6 893 870,5	478 582,9	6 893 870,9	6,0	2	0	1	0	0	grøft rundt. Til dels ødelagt av skogsmaskiner
60	6435	6444	478 620,0	6 893 905,3	478 620,3	6 893 907,7	7,8	0	1	1	0	0	Groper rundt
61	6445	6446	478 685,0	6 893 892,3	478 685,5	6 893 892,1	7,7	0	1	2	0	0	Groper rundt
62	6447	6448	478 686,0	6 893 942,0									Funnet av Øivind Trier, ikke verifisert a arkeologer
63	6449	6456	478 550,2	6 893 767,0	478 549,9	6 893 764,1	8,7	0	1	0	0	0	Skadet av skogsmaskiner
64	6457	6460	478 548,3	6 893 697,3	478 548,5	6 893 696,0	6,0	0	1	0	0	0	Registrert i felt som A002
65	6461	6467	478 448,2	6 893 728,8	478 449,5	6 893 727,1	8,5	2	1	0	0	1	Groper rundt. Dobbel kullmile
66	6468	6476	478 391,3	6 893 622,9				0	1	1	0	0	Anomali 75
67	6479	6482	477 820,3	6 894 180,7	477 820,3	6 894 181,1	9,4	2	0	0	0	0	Den er skadet på grunn av veibyging
68	6483	6484	477 861,1	6 894 161,6	477 860,9	6 894 161,1	6,6	2	1	2	0	0	Svak grøft og groper
69	6103	6107	478 102,2	6 894 785,8	478 102,0	6 894 786,0	6,9	2	0	0	0	0	Bekreftet som kullmile
70	6095	6095	478 193,2	6 894 802,2	478 193,0	6 894 801,1	5,8	0	1	2	0	1	Dobbel kullmile

The corrected positions in DTM (Table 2) were obtained by accurately measuring the extent of the circular ditch or circular pattern of pits along the circumference. The radius is measured from the kiln centre to the middle of the ditch. This means that the true size of the entire kiln structure is somewhat larger than what the radius suggests. There accurate measurements were made for the purpose of training an automatic detection method. For some kilns, it was difficult to define the kiln centre, and/or the kiln structure was rejected as suitable for training of a detection method. In each of these cases, no centre point and radius were measured accurately, but left blank in Table 2.

Table 3. Charcoal kiln characteristics. These are used in Table 2.

Key	Characteristic	Description
Di	Ditch	0=no ditch, 1=circle segment, 2=full circle
PI	Pit inside	0=no pits inside kiln, 1=one or more pits inside kiln
M	Mound	0=no central mound, 1=weak central mound, 2=distinct central mound
PO	Pit outside	0=no pits outside nor on circumference, 1=one or more pits outside or on circumference
DK		Double kiln

The centre point and radius were also measured accurately for number of charcoal kilns without photo documentation (Table 4, Table 5), again for the purpose of training an automatic method. These were inside a 3×3 km² area (Figure 39), which also includes the kilns with photo documentation.

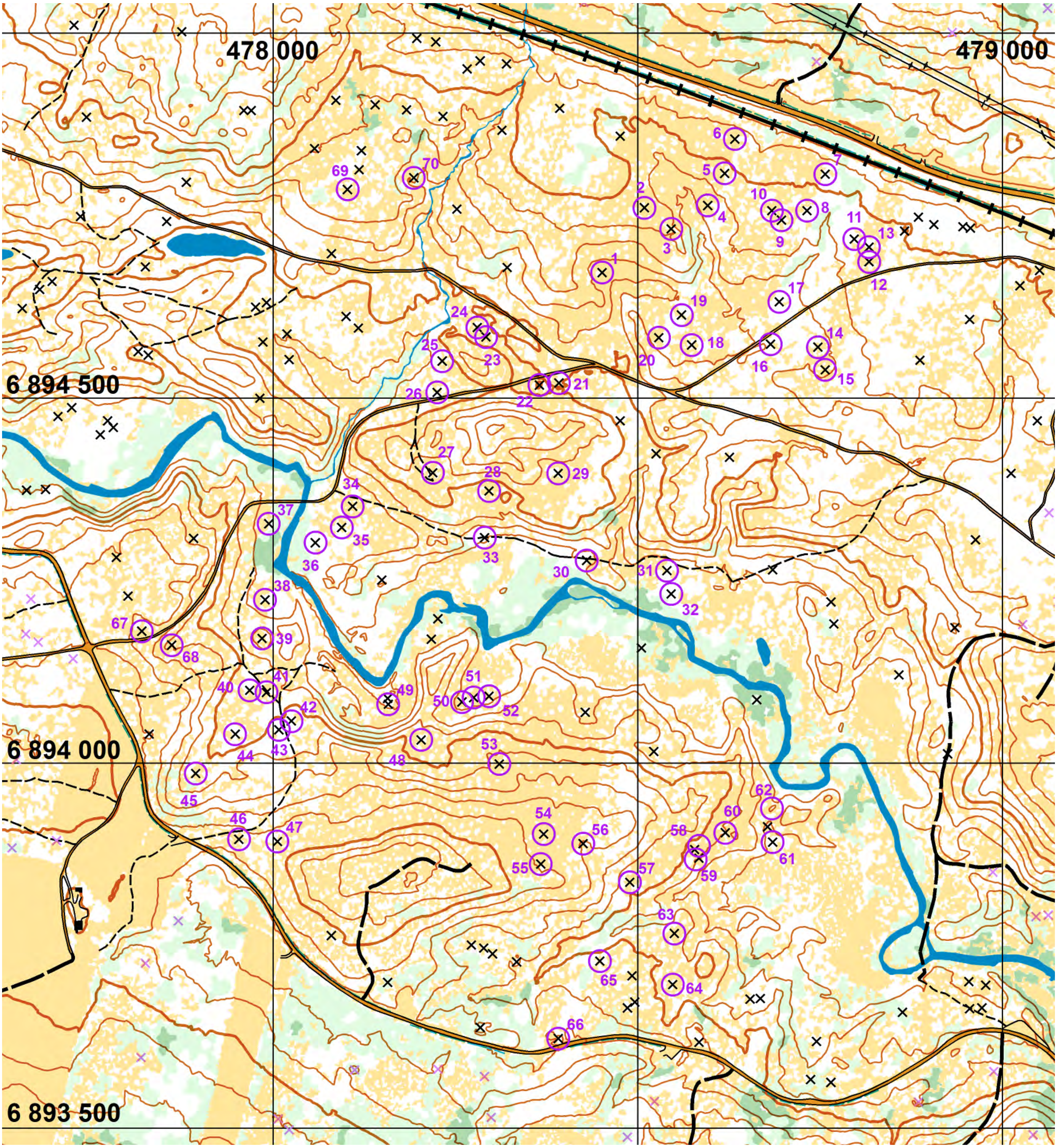

Figure 38. Map of photographed charcoal kilns (purple circles), scale 1:7 500, grid line interval 500 m

Table 4. Charcoal kilns with field verification, but without photo documentation.

GPS position		Corrected position in DTM			Chraracteristics					
east	north	east	north	rad	Di	PI	M	PO	DK	Comment (in Norwegian)
477 480,0	6 894 804,9	477 801,0	6 894 229,0	7,6	2	0	0	0	1	Dobbel kullmile, skadet av skogsbilvei
477 530,7	6 894 947,1	477 530,7	6 894 948,1	8,1	1	1	0	0	1	Anomali 6- Dobbel kullmile. Det er 2 groper utenfor for den. Mulig uttak for kull
477 583,8	6 894 815,6				0	1	1	0	0	Registrert i felt som e11
477 595,5	6 894 807,6	477 595,3	6 894 808,0	9,6	0	1	1	0	0	Bekreftet som kullmile
477 598,9	6 895 032,7				0	1	0	0	0	Registrert i felt som km1
477 605,1	6 894 973,3	477 605,2	6 894 973,3	8,0	1	1	1	0	0	Registrert i felt som e71- Groper og grøft
477 655,6	6 894 623,0				1	0	1	0	0	Bekreftet som kullmile
477 661,6	6 894 374,1	477 662,0	6 894 374,5	8,7	2	1	2	0	0	Groper og grøft
477 680,2	6 894 649,5	477 679,3	6 894 650,1	7,0	0	1	1	0	0	Bekreftet som kullmile
477 687,6	6 894 375,4	477 689,0	6 894 375,0	5,6	2	1	1	0	0	Groper og grøft
477 696,7	6 894 660,3	477 696,2	6 894 660,0	7,0	2	0	2	1	0	Bekreftet som kullmile
477 705,1	6 894 475,2				0	1	0	0	0	Registrert i felt som e7- 2 groper rundt
477 724,2	6 894 486,6				0	1	0	0	0	Registrert i felt som e6- Flere groper rundt den. Den er vest for 149
477 724,9	6 895 113,3	477 725,5	6 895 112,9	4,3	2	0	2	0	0	Anomali 111-Tuft E13 ved
477 727,3	6 895 011,4	477 727,5	6 895 010,3	8,1	2	1	2	0	1	Dobbel kullmile
477 736,3	6 894 748,9	477 736,9	6 894 749,1	7,0	2	1	0	0	0	Bekreftet som kullmile
477 744,0	6 894 885,0	477 744,0	6 894 884,1	7,6	0	1	0	0	0	Bekreftet som kullmile
477 763,0	6 894 449,6	477 763,8	6 894 452,2	9,8	2	1	2	0	0	Veldig stor kullmile
477 772,6	6 894 469,1	477 772,2	6 894 467,8	6,0	2	0	2	0	0	Bekreftet som kullmile
477 780,8	6 894 459,5	477 782,0	6 894 459,0	6,5	2	1	2	0	0	Bekreftet som kullmile
477 784,7	6 894 281,7	477 785,0	6 894 280,7	9,0	1	1	0	0	0	Groper og grøft
477 801,2	6 894 229,3				2	0	0	0	0	Svak grøft
477 814,7	6 894 563,6	477 813,9	6 894 562,5	7,3	0	1	1	0	0	Bekreftet som kullmile
477 824,6	6 894 679,8	477 825,0	6 894 680,0	7,5	2	1	2	0	0	Bekreftet som kullmile
477 828,5	6 894 558,8				0	1	0	0	0	Bekreftet som kullmile
477 830,2	6 894 039,6	477 830,3	6 894 039,3	7,4	2	1	1	0	0	Groper og grøft, men mest grøft
477 834,6	6 895 123,0	477 833,3	6 895 121,1	9,3	1	1	1	0	1	Dobbel kullmile
477 853,7	6 894 742,4	477 853,5	6 894 742,5	6,3	0	1	0	0	0	Groper rundt. Ingen grøft
477 874,7	6 895 001,7	477 875,3	6 895 002,1	8,4	2	1	0	0	0	Maurtuer på toppen
477 881,3	6 894 795,5	477 881,0	6 894 795,1	8,1	1	0	1	0	0	Vegetasjon i den skiller seg ved å være grønnere enn rundt
477 890,6	6 894 308,2				2	1	1	0	0	Befinner seg på kanten av terreng i sør. Groper og grøft, men mest grøft
477 949,4	6 895 076,7	477 951,3	6 895 077,1	8,9	2	0	0	1	0	Den er vanskelig å se i terreng. Det er 2 groper utenfor den
477 959,8	6 894 893,8	477 961,9	6 894 897,7	5,5	0	1	1	0	0	Registrert i felt som e24
477 970,3	6 894 894,4	477 970,5	6 894 894,7	5,8	0	1	1	0	0	Bekreftet som kullmile
477 975,5	6 894 625,2	477 974,7	6 894 624,9	9,6	1	1	2	0	1	Dobbel kullmile. Den yngste er ikke tømt
477 982,5	6 894 499,9	477 983,0	6 894 501,7	6,7	2	0	0	0	0	Bekreftet som kullmile
477 986,3	6 894 576,9				0	0	0	0	0	Registrert i felt som e3- Koietuft midt på den, identifisert på grunn av ildsted i stein. Ingen synlig groper eller grøft
477 991,1	6 894 630,6				1	0	0	0	0	Registrert i felt som e2- Den er ca 10 m Ï for 145
478 011,6	6 895 055,3	478 012,0	6 895 054,1	7,1	0	1	0	0	0	Det er en grop innenfor den. Mulig senere uttak av kull
478 019,3	6 894 587,9	478 018,3	6 894 588,5	7,5	1	0	0	0	0	Ødelagt. Går ned mot bekk
478 022,4	6 894 552,8	478 022,3	6 894 553,3	5,5	2	0	2	0	0	Bekreftet som kullmile
478 057,5	6 894 841,8	478 058,5	6 894 843,1	8,7	2	0	1	0	0	Det er to groper innenfor den. Mulig senere uttak av kull
478 079,6	6 893 763,5	478 080,3	6 893 764,0	8,8	0	1	2	0	0	Groper rundt. Stor forhøyning

GPS position		Corrected position in DTM			Chraracteristics					
east	north	east	north	rad	Di	PI	M	PO	DK	Comment (in Norwegian)
478 079,6	6 894 698,1	478 080,0	6 894 697,5	8,0	1	1	1	0	0	Skiltet
478 086,3	6 894 907,9	478 087,9	6 894 907,3	8,3	1	0	2	0	0	Rektangulµr kull uttak i den fra sekundµr bruk
478 100,4	6 894 611,8	478 099,7	6 894 612,5	7,8	1	1	2	0	0	Svak grøft og groper rundt
478 116,9	6 894 596,1	478 116,0	6 894 598,0	7,0	2	1	2	0	0	Bekreftet som kullmile
478 118,1	6 894 812,7	478 118,0	6 894 813,0	8,0	2	1	0	0	1	Stor grop SV ved den
478 121,0	6 894 838,6	478 121,0	6 894 839,5	5,7	0	1	0	0	0	Bekreftet som kullmile
478 140,4	6 894 901,8	478 140,3	6 894 902,3	6,2	1	1	2	0	1	Dobbel kullmile. Den er skadet av skogsdrift. Det er tatt bilde av den
478 148,6	6 894 251,4	478 148,5	6 894 252,0	6,4	2	0	2	0	0	Bekreftet som kullmile
478 156,8	6 893 700,2	478 157,0	6 893 702,5	8,1	2	1	0	0	0	grøft rundt og stor grop
478 157,2	6 894 089,2	478 157,3	6 894 093,1	8,6	0	1	1	0	0	Bekreftet kullmile
478 182,7	6 894 894,7	478 183,5	6 894 895,7	5,2	1	1	2	0	0	Bekreftet som kullmile
478 197,5	6 894 993,5	478 197,3	6 894 992,7	7,9	2	1	2	0	0	Bekreftet som kullmile
478 217,0	6 894 169,6				0	1	0	0	0	Registrert i felt som e55
478 223,4	6 894 988,1	478 223,5	6 894 987,7	6,6	0	1	0	0	0	Ingen grøft, men flere groper rundt
478 226,2	6 894 197,9	478 225,5	6 894 197,5	7,8	1	1	0	0	0	Anomali 26
478 232,9	6 894 885,8	478 233,0	6 894 886,0	7,1	0	1	0	1	0	Grop ved den
478 251,5	6 894 758,6	478 251,3	6 894 758,5	8,5	2	1	1	0	0	Bekreftet som kullmile
478 266,3	6 894 951,5	478 266,0	6 894 951,0	7,8	2	0	2	0	0	Bekreftet som kullmile
478 272,4	6 893 750,8	478 273,1	6 893 750,1	6,4	0	1	2	0	0	Anomali 74
478 283,9	6 893 638,3	478 285,5	6 893 638,1	8,8	2	1	2	0	0	Stor kullmile med grøft. Høyde på ca 0,4 m
478 284,0	6 894 961,6	478 282,9	6 894 961,1	5,8	0	1	0	0	0	Anomali 60
478 289,3	6 893 746,7				2	0	2	0	0	Anomali 73
478 300,8	6 893 739,2	478 301,0	6 893 737,7	7,1	0	1	1	0	0	Groper rundt, koietuft på toppen
478 313,6	6 894 867,4	478 314,7	6 894 867,3	7,3	2	1	1	0	0	Groper og grøft
478 320,3	6 894 957,9				0	0	0	0	0	Anomali 59- Sår etter skogsmaskin på den
478 321,2	6 894 679,4	478 321,0	6 894 679,0	5,7	2	1	0	0	0	Bekreftet som kullmile
478 333,8	6 893 727,9	478 333,1	6 893 727,5	6,8	2	1	1	0	0	Groper og grøft rundt
478 392,7	6 894 896,7	478 393,3	6 894 897,5	10,5	0	1	2	0	1	Det er flere groper
478 427,9	6 894 070,1				0	1	1	0	0	Halvdelen av den er ødelagt. Store furutrær i midten
478 475,9	6 894 859,3	478 473,9	6 894 860,1	9,0	0	1	2	1	1	Doble kullmile. Groper utenfor
478 476,4	6 894 469,5				0	1	0	0	0	Registrert i felt som e31
478 486,3	6 893 665,3	478 486,5	6 893 665,5	8,7	0	1	0	0	0	Groper rundt.
478 491,6	6 893 709,3	478 491,9	6 893 711,7	8,6	0	1	0	0	0	Flatt, ingen forhøyning
478 495,5	6 893 673,3	478 497,5	6 893 672,2	7,9	0	1	0	0	0	Groper rundt.
478 505,0	6 894 158,1	478 505,3	6 894 158,3	5,7	2	0	2	0	0	Grøft rundt. Den er ca 0,4 m høy og går i ett med vegetasjon
478 522,4	6 894 016,3	478 522,0	6 894 015,4	7,6	2	1	2	0	0	Groper og grøft rundt
478 525,4	6 894 424,0	478 524,3	6 894 426,1	6,7	1	1	2	0	0	Groper rundt
478 577,8	6 893 881,9				0	0	0	0	0	Registrert i felt som e70. Ikke lett å se hva punktet markerer på DTM. Feilplassert.
478 584,0	6 893 617,8				0	1	1	0	0	Groper rundt. Den befinner seg ved veien
478 625,6	6 894 419,4	478 626,3	6 894 418,3	6,4	1	1	1	0	0	Groper og grøft
478 654,5	6 893 677,0				0	1	0	0	0	Registrert i felt som e64- Befinner seg ved siden av kullmile 308
478 662,9	6 894 086,6	478 662,9	6 894 087,1	7,5	0	1	0	0	0	Groper rundt som er fulle av vann
478 667,7	6 893 677,6	478 668,0	6 893 679,1	8,7	0	1	0	0	0	Groper rundt
478 677,7	6 893 913,0	478 677,2	6 893 913,8	6,7	2	1	0	0	0	Den er vanskelig å se i terrenget.
478 684,6	6 894 265,3	478 685,0	6 894 265,0	6,6	2	1	2	0	0	grøft og groper
478 736,7	6 893 567,3	478 735,9	6 893 566,5	8,3	0	1	2	0	0	Groper rundt
478 744,9	6 893 619,1	478 745,0	6 893 619,0	7,0	2	1	2	0	0	Stor forhøyning. grøft rundt og noen groper i sør
478 764,8	6 894 221,0	478 765,2	6 894 220,5	7,4	2	1	2	0	0	grøft og groper, men mest grøft
478 765,2	6 893 562,7	478 765,0	6 893 561,6	9,4	0	1	0	0	0	Flatt, ingen forhøyning. Groper rundt
478 768,6	6 894 190,6	478 767,9	6 894 191,7	4,0	0	1	0	0	0	Registrert i felt som e34
478 858,4	6 894 121,3	478 858,0	6 894 121,7	6,1	0	1	0	0	0	Anomali 27
478 863,3	6 893 658,6				0	1	0	0	0	Flatt, ingen forhøyning. Groper rundt
478 866,4	6 894 729,4	478 866,9	6 894 730,5	6,2	0	1	2	0	0	Bekreftet som kullmile
478 885,4	6 894 747,7	478 885,9	6 894 747,1	6,3	1	0	2	0	0	Bekreftet som kullmile
478 886,7	6 894 552,3	478 887,3	6 894 552,1	7,6	0	1	2	0	1	Groper rundt. Dobbel kullmile
478 905,8	6 894 737,7	478 906,0	6 894 737,1	6,8	0	1	2	0	0	Bekreftet som kullmile
478 924,8	6 894 012,6				0	1	0	0	0	Veien går gjennom den
478 934,8	6 894 186,3	478 934,7	6 894 187,1	7,8	0	1	2	0	0	Groper og grøft
478 945,9	6 894 734,9	478 945,5	6 894 735,1	5,7	0	1	2	0	0	Bekreftet som kullmile
478 953,9	6 893 701,1				0	1	0	0	0	Registrert i felt som e67

GPS position		Corrected position in DTM			Chraracteristics					
east	north	east	north	rad	Di	Pl	M	PO	DK	Comment (in Norwegian)
478 954,8	6 894 608,3	478 953,5	6 894 608,1	8,8	0	1	0	0	0	Groper rundt
478 955,4	6 893 663,7	478 953,9	6 893 663,1	8,0	0	1	1	0	0	Groper rundt
478 956,4	6 894 732,5	478 955,9	6 894 733,3	6,0	0	1	2	0	0	Anomali 10- Ved siden av 878
478 963,4	6 894 306,5	478 963,7	6 894 308,1	7,1	0	1	0	0	0	Bekreftet som kullmile
478 972,1	6 893 665,1	478 972,9	6 893 667,1	8,1	0	1	2	0	0	Groper rundt
478 977,2	6 893 695,9	478 975,9	6 893 696,1	7,1	2	1	0	0	1	grøft og groper rundt
479 012,4	6 894 396,9				0	1	2	0	0	Anomali 93
479 024,4	6 894 654,5	479 024,0	6 894 656,5	8,6	0	1	0	0	0	Groper rundt
479 048,3	6 894 468,5	479 048,3	6 894 468,1	5,2	0	1	0	0	0	Groper rundt
479 050,6	6 894 675,1	479 051,0	6 894 675,0	6,5	2	0	2	0	0	grøft rundt. Bekkeløp i kant
479 081,2	6 894 622,7	479 081,3	6 894 624,1	6,7	1	1	1	0	0	grøft på ene siden (SV)
479 117,0	6 894 138,6	479 116,0	6 894 138,5	8,5	2	1	1	0	0	grøft rundt og groper. Dobbel kullmile?

Table 5. Visually confirmed charcoal kilns within the 3×3 km² training area at Sandom, with corrected positions.

GPS position		Corrected position in DTM			Comment
east	north	east	north	rad	(in Norwegian)
477 010,6	6 894 129,1	477 009,9	6 894 130,3	7,2	
477 012,8	6 894 277,8	477 011,5	6 894 278,5	5,8	
477 016,0	6 895 059,2	477 016,7	6 895 059,7	8,2	
477 016,3	6 894 189,4	477 015,1	6 894 191,2	7,9	
477 089,3	6 894 778,1	477 089,7	6 894 777,7	6,5	
477 094,7	6 894 331,4	477 095,7	6 894 331,5	8,4	
477 110,4	6 894 358,9	477 111,1	6 894 358,4	7,3	
477 123,3	6 894 992,2	477 122,9	6 894 991,7	6,2	
477 125,2	6 896 091,0				
477 149,0	6 894 399,7	477 148,7	6 894 400,5	8,2	
477 155,7	6 895 258,1	477 156,7	6 895 257,1	9,6	
477 157,5	6 893 904,6	477 157,9	6 893 905,3	8,7	
477 161,9	6 893 941,9	477 161,3	6 893 941,5	6,0	
477 175,9	6 894 681,8	477 176,7	6 894 681,5	7,7	
477 179,0	6 894 874,1	477 176,3	6 894 875,1	5,7	
		477 180,0	6 894 668,3	8,0	Lagt til av ØDT
477 179,9	6 895 022,3	477 180,3	6 895 022,0	10,2	
477 185,7	6 894 860,3	477 185,9	6 894 859,7	7,6	
477 190,2	6 894 218,4	477 188,3	6 894 219,8	9,0	
477 203,5	6 895 922,9	477 204,7	6 895 923,1	8,4	
477 215,8	6 893 835,5	477 216,9	6 893 835,3	6,6	
477 216,2	6 894 180,3	477 216,7	6 894 180,9	6,9	
477 217,2	6 895 305,3				
477 221,8	6 894 280,0	477 222,5	6 894 281,1	8,5	
477 237,9	6 893 411,0				
477 238,7	6 894 179,0	477 238,7	6 894 179,1	8,2	
477 249,2	6 893 573,1	477 247,5	6 893 574,3	7,1	
477 263,7	6 893 795,2	477 262,3	6 893 793,9	7,1	
477 273,6	6 893 573,4				
477 275,3	6 893 660,9	477 274,9	6 893 660,5	7,6	
477 288,2	6 893 809,9	477 286,3	6 893 812,1	7,8	
477 302,3	6 894 258,1	477 302,3	6 894 257,1	5,0	
477 323,2	6 894 837,9	477 323,7	6 894 837,7	8,4	
477 327,3	6 893 820,6	477 328,0	6 893 820,0	9,0	Haug
477 348,1	6 895 014,1	477 347,9	6 895 015,1	8,0	
477 351,9	6 894 352,4	477 350,3	6 894 351,7	10,7	
477 364,1	6 894 332,0	477 363,5	6 894 330,3	8,5	
477 376,2	6 894 181,6	477 375,9	6 894 181,5	9,2	
477 378,2	6 895 142,6	477 378,5	6 895 143,7	8,1	
477 383,3	6 894 592,8	477 381,7	6 894 591,1	8,4	
477 388,8	6 893 741,0	477 387,3	6 893 742,5	7,2	
477 391,0	6 893 831,6	477 390,9	6 893 833,3	6,6	
477 409,6	6 893 477,8				
477 416,1	6 893 574,0	477 414,5	6 893 573,3	6,7	

GPS position		Corrected position in DTM			Comment
east	north	east	north	rad	(in Norwegian)
477 435,5	6 893 270,6	477 435,5	6 893 270,5	5,7	
477 448,2	6 894 193,7	477 450,3	6 894 195,5	7,3	
477 450,8	6 894 012,7	477 450,9	6 894 011,3	9,4	
477 470,3	6 893 924,0	477 471,9	6 893 924,5	9,1	
477 478,9	6 895 758,3	477 477,7	6 895 757,5	8,8	
477 490,4	6 895 684,2	477 489,9	6 895 684,1	7,4	
477 512,4	6 893 913,4	477 513,7	6 893 914,1	6,3	
477 534,9	6 894 162,0	477 535,1	6 894 161,1	6,3	
477 560,8	6 894 280,5	477 561,1	6 894 278,9	7,7	
477 597,7	6 893 889,9	477 597,5	6 893 889,1	8,6	
477 613,4	6 894 012,0	477 613,9	6 894 011,5	6,1	
477 622,1	6 894 169,0	477 620,5	6 894 169,1	6,2	
477 641,6	6 893 884,1	477 640,9	6 893 886,1	7,1	
477 648,1	6 894 005,5	477 648,1	6 894 005,5	9,2	
477 660,7	6 894 176,8	477 660,9	6 894 176,1	9,4	
477 667,6	6 894 225,4	477 667,9	6 894 223,7	8,5	
477 677,6	6 894 166,4	477 677,5	6 894 168,9	7,6	
477 703,1	6 893 893,8	477 703,3	6 893 893,3	6,6	
477 726,2	6 894 143,0	477 724,3	6 894 144,3	7,4	
477 784,9	6 893 191,3	477 784,1	6 893 190,9	6,0	
477 791,7	6 895 861,8	477 790,9	6 895 859,7	6,8	
477 819,0	6 893 597,4	477 818,1	6 893 600,1	7,6	
477 824,6	6 893 726,2	477 824,7	6 893 726,3	9,0	
477 837,4	6 895 756,2	477 834,7	6 895 755,9	8,6	
477 869,7	6 893 783,9	477 869,1	6 893 785,9	8,6	
477 884,6	6 895 847,5	477 882,7	6 895 848,9	6,7	
477 917,9	6 895 555,8	477 917,5	6 895 555,1	8,9	
477 964,7	6 893 372,8	477 966,5	6 893 371,9	8,3	
477 983,8	6 895 203,3	477 984,1	6 895 203,3	7,1	
478 007,4	6 893 512,8	478 006,9	6 893 512,1	7,7	
478 021,6	6 893 498,2	478 021,9	6 893 498,7	7,9	
478 040,2	6 895 606,6	478 038,9	6 895 606,7	7,6	
478 072,1	6 893 195,1	478 072,3	6 893 194,5	7,7	
478 077,9	6 895 451,0	478 078,3	6 895 450,5	7,5	
478 105,0	6 893 438,5	478 104,9	6 893 438,7	8,1	Litt utydelig
478 111,6	6 893 580,4	478 110,9	6 893 580,1	8,7	
478 119,9	6 895 570,5	478 119,9	6 895 569,5	7,5	
478 142,5	6 893 080,7	478 142,5	6 893 080,7	7,8	
478 182,2	6 895 277,2	478 181,3	6 895 276,5	7,0	
478 198,5	6 895 409,7	478 197,0	6 895 409,3	7,0	
478 206,9	6 893 061,3				
478 214,4	6 895 458,9	478 213,7	6 895 455,7	6,8	
478 219,1	6 895 659,0	478 217,7	6 895 656,1	7,8	
478 226,2	6 893 581,4	478 225,9	6 893 581,1	8,5	
478 227,8	6 895 148,3	478 228,3	6 895 148,3	8,8	
478 228,2	6 895 165,0	478 231,1	6 895 165,1	8,5	
478 231,9	6 893 376,4	478 231,5	6 893 376,5	6,4	
478 286,2	6 895 500,6	478 287,1	6 895 500,1	7,4	
478 289,6	6 893 321,8	478 289,5	6 893 321,9	8,0	
478 290,0	6 893 570,5	478 292,1	6 893 569,7	7,8	
478 299,1	6 893 515,4	478 298,3	6 893 516,4	8,1	
478 301,3	6 895 639,5	478 300,3	6 895 638,7	7,4	
478 333,8	6 895 430,0	478 333,3	6 895 429,5	7,2	
478 345,0	6 895 491,5	478 345,7	6 895 491,7	7,6	
478 366,4	6 895 630,4	478 364,9	6 895 629,1	7,2	
478 420,5	6 893 196,6				
478 426,2	6 895 042,4	478 425,9	6 895 042,1	7,1	

GPS position		Corrected position in DTM			Comment
east	north	east	north	rad	(in Norwegian)
478 449,0	6 893 346,6	478 445,4	6 893 348,1	8,8	
478 456,9	6 893 329,2	478 457,9	6 893 329,1	6,4	
478 460,1	6 895 456,2	478 459,7	6 895 454,9	7,0	
478 469,6	6 895 170,4	478 469,5	6 895 170,1	7,6	
478 486,4	6 893 487,7				
478 497,0	6 895 283,9	478 496,9	6 895 282,7	6,6	
478 497,2	6 893 248,7	478 498,7	6 893 250,9	7,2	
478 497,8	6 895 046,6	478 497,5	6 895 047,7	8,7	
478 510,5	6 893 354,9	478 510,3	6 893 355,7	7,0	
478 514,5	6 893 100,2	478 514,3	6 893 100,1	7,1	
478 523,3	6 893 537,1	478 522,7	6 893 539,1	5,6	
478 540,6	6 893 358,5	478 541,9	6 893 361,7	8,9	
478 562,7	6 893 253,0	478 563,1	6 893 253,5	7,5	
478 587,9	6 893 441,9	478 587,7	6 893 441,9	7,2	
478 601,3	6 893 280,8	478 601,0	6 893 281,7	7,4	
478 605,7	6 895 271,2	478 605,3	6 895 271,1	7,4	
478 653,8	6 893 186,7	478 654,9	6 893 185,1	6,4	
478 653,9	6 893 437,2	478 653,9	6 893 437,1	5,9	
478 670,3	6 893 259,6	478 671,3	6 893 259,5	7,8	
478 670,8	6 895 383,5	478 670,9	6 895 383,1	6,6	
478 672,0	6 895 146,6	478 672,5	6 895 147,1	7,1	
478 696,3	6 893 288,6	478 695,5	6 893 289,1	6,8	
478 705,8	6 893 465,6	478 704,9	6 893 464,7	7,3	
478 724,9	6 893 168,9	478 725,5	6 893 170,1	7,1	
478 726,1	6 893 389,9	478 726,5	6 893 390,1	7,4	
478 737,9	6 893 156,4	478 737,9	6 893 159,1	9,1	
478 745,0	6 894 960,7	478 745,3	6 894 959,1	7,7	
478 753,9	6 893 379,4	478 754,3	6 893 379,5	8,9	
478 779,5	6 895 147,8	478 778,3	6 895 148,9	6,9	
478 789,9	6 895 254,5	478 790,7	6 895 254,5	7,7	
478 802,5	6 893 271,3	478 801,7	6 893 275,3	8,0	
478 812,5	6 893 267,2	478 812,1	6 893 267,5	5,9	
478 853,8	6 895 133,1	478 853,7	6 895 133,1	7,3	
478 857,6	6 893 142,9	478 858,3	6 893 145,3	9,1	
478 885,4	6 893 536,3	478 885,1	6 893 537,5	7,2	
478 894,3	6 893 418,4	478 894,5	6 893 419,1	8,8	
478 915,9	6 893 309,3	478 917,3	6 893 309,5	5,4	
478 930,6	6 895 001,5	478 930,0	6 895 003,5	6,3	
478 974,8	6 893 410,5	478 976,1	6 893 409,3	7,5	
478 978,2	6 893 283,0	478 980,3	6 893 284,9	7,2	
478 987,3	6 893 851,1	478 987,9	6 893 851,1	7,8	
478 988,2	6 893 577,9	478 988,1	6 893 579,9	8,2	
479 009,2	6 893 360,6	479 009,7	6 893 360,1	7,3	
479 013,7	6 893 317,3	479 012,5	6 893 319,7	7,6	
479 027,6	6 894 189,8	479 026,3	6 894 191,7	8,1	
479 035,4	6 893 326,8	479 034,3	6 893 327,7	6,9	
479 041,9	6 893 490,7	479 041,3	6 893 492,3	6,9	
479 046,1	6 893 790,2	479 047,7	6 893 791,0	7,0	
479 061,4	6 893 217,5	479 062,1	6 893 218,3	8,6	
479 062,3	6 895 033,6				
479 063,0	6 893 792,5	479 063,1	6 893 792,7	7,9	
479 064,4	6 894 342,6	479 061,9	6 894 341,5	10,6	
479 076,6	6 894 221,5	479 076,7	6 894 224,5	8,1	
479 079,7	6 893 220,1	479 079,7	6 893 222,1	7,2	
479 082,2	6 894 238,6	479 081,9	6 894 238,7	6,7	
479 094,8	6 894 353,8	479 094,3	6 894 353,9	5,3	Stor flat grop
479 095,5	6 895 328,0	479 094,7	6 895 326,3	11,8	

GPS position		Corrected position in DTM			Comment
east	north	east	north	rad	(in Norwegian)
479 103,0	6 893 401,0	479 103,1	6 893 402,3	7,2	
479 113,9	6 893 785,2	479 113,3	6 893 785,9	6,1	
479 124,8	6 893 577,9	479 123,9	6 893 578,3	6,5	
479 131,7	6 893 034,0	479 131,5	6 893 036,1	10,1	
479 137,6	6 893 580,1	479 136,9	6 893 579,3	8,9	
479 153,8	6 893 365,0	479 154,1	6 893 367,9	8,6	
479 187,0	6 893 432,9	479 187,1	6 893 432,1	6,6	
479 187,8	6 893 811,9	479 188,3	6 893 811,9	9,1	
479 203,3	6 893 806,4	479 202,5	6 893 806,7	8,8	
479 208,9	6 893 264,8	479 209,9	6 893 266,5	8,0	
479 211,5	6 893 103,5	479 212,3	6 893 102,9	5,9	
479 224,1	6 893 397,1	479 223,8	6 893 397,1	6,4	
479 232,7	6 893 319,9	479 232,9	6 893 319,7	6,5	
479 233,6	6 894 043,7	479 233,9	6 894 045,1	8,9	
479 236,7	6 893 178,6	479 236,5	6 893 180,5	7,0	
479 260,9	6 894 053,6	479 259,9	6 894 055,9	6,4	
479 265,3	6 895 031,5	479 264,9	6 895 031,7	7,8	
479 285,6	6 894 105,2	479 285,3	6 894 108,0	7,8	
479 300,8	6 894 364,1	479 299,3	6 894 365,3	9,5	
479 304,7	6 893 940,4	479 305,5	6 893 942,1	8,1	
479 306,4	6 893 195,3	479 306,0	6 893 195,5	8,3	
479 328,1	6 894 083,1	479 327,1	6 894 085,7	8,0	
479 355,3	6 893 499,5				
479 367,4	6 893 346,5	479 365,5	6 893 346,9	6,4	
479 390,2	6 894 132,1	479 389,9	6 894 133,3	6,1	
479 390,6	6 893 654,7	479 389,3	6 893 657,1	8,5	
479 397,5	6 894 169,0	479 395,9	6 894 167,5	9,1	
479 411,0	6 894 050,2	479 412,3	6 894 049,7	9,8	
479 429,6	6 894 354,2	479 429,0	6 894 357,0	8,7	
479 430,7	6 894 504,0	479 430,3	6 894 504,0	8,2	
479 434,8	6 893 961,7	479 432,7	6 893 963,5	7,4	
479 450,1	6 894 836,4	479 450,1	6 894 837,5	7,1	
479 453,0	6 893 744,9	479 453,5	6 893 744,5	6,9	
479 455,2	6 893 532,4	479 455,7	6 893 533,3	7,0	
479 473,4	6 895 087,7	479 472,7	6 895 089,1	5,8	
479 477,8	6 894 152,9	479 478,1	6 894 153,9	7,0	
479 494,3	6 893 345,0	479 494,1	6 893 345,9	8,2	
479 495,3	6 895 000,6	479 495,3	6 895 000,5	7,1	
479 515,2	6 894 364,9	479 516,1	6 894 365,7	8,5	
479 522,0	6 893 721,9	479 521,0	6 893 721,9	7,7	
479 545,7	6 894 442,2	479 546,2	6 894 442,1	6,5	
479 547,6	6 894 224,5	479 547,9	6 894 225,5	6,3	
479 554,7	6 894 424,9	479 555,5	6 894 424,7	6,3	
479 571,4	6 894 317,3	479 572,3	6 894 317,3	9,4	
479 574,5	6 894 061,4	479 573,5	6 894 062,3	7,9	
479 578,1	6 895 101,0	479 577,9	6 895 100,1	6,5	
479 603,5	6 893 048,8	479 600,5	6 893 048,3	4,9	
479 606,6	6 894 298,2	479 607,7	6 894 299,5	7,2	
479 613,6	6 893 852,3	479 615,3	6 893 855,8	8,1	
479 622,2	6 893 231,0	479 621,3	6 893 232,1	6,3	
479 647,3	6 894 449,1	479 647,5	6 894 451,3	6,1	
479 654,3	6 894 037,4	479 654,3	6 894 040,1	7,3	
479 666,2	6 893 227,8				
479 668,3	6 894 063,3	479 670,7	6 894 062,5	8,5	
479 675,7	6 894 346,8				
479 676,4	6 893 216,7	479 675,7	6 893 217,9	8,4	
479 682,0	6 895 165,6	479 682,1	6 895 163,7	8,0	

GPS position		Corrected position in DTM			Comment
east	north	east	north	rad	(in Norwegian)
479 682,7	6 894 400,6	479 682,1	6 894 401,9	5,8	
479 683,7	6 894 367,5				
479 684,3	6 893 082,7	479 684,7	6 893 082,3	4,5	
479 702,0	6 894 008,2	479 701,7	6 894 009,3	6,8	
479 714,8	6 893 288,2	479 717,9	6 893 288,1	6,0	
479 718,4	6 894 125,6	479 717,5	6 894 126,7	9,0	
479 728,4	6 892 508,9				
479 732,8	6 893 083,1	479 732,9	6 893 085,7	5,4	
479 737,1	6 893 233,5	479 737,3	6 893 234,2	6,5	
479 742,3	6 892 613,9				
479 770,9	6 893 068,3	479 768,7	6 893 070,7	6,7	
479 772,8	6 892 807,3				
479 777,0	6 892 908,7				
479 777,9	6 892 947,8				
479 786,1	6 892 972,9				
479 789,1	6 894 192,4	479 789,5	6 894 195,1	7,6	
479 805,6	6 892 470,3				
479 814,7	6 892 831,6				
479 820,4	6 894 234,5	479 819,5	6 894 236,1	5,4	
479 835,5	6 893 166,3	479 834,9	6 893 166,9	7,0	
479 850,0	6 893 161,4	479 850,5	6 893 160,5	4,9	
479 850,3	6 892 724,0				
479 852,9	6 894 093,1	479 852,1	6 894 094,7	10,1	
479 854,6	6 894 340,3	479 854,1	6 894 343,7	6,6	
479 859,4	6 892 540,6				
479 862,4	6 893 142,1	479 862,0	6 893 144,7	8,7	
479 865,3	6 887 166,4				
479 866,1	6 894 415,3	479 865,9	6 894 414,7	8,3	
479 874,1	6 894 094,4	479 873,3	6 894 094,9	8,0	
479 889,7	6 892 895,3				
479 905,8	6 892 600,8				
479 908,4	6 892 671,1				
479 918,8	6 893 988,8	479 918,9	6 893 991,1	7,6	
479 921,4	6 892 428,2				
479 923,6	6 894 263,5	479 922,3	6 894 264,9	8,4	
479 925,7	6 892 504,1				
479 939,4	6 892 572,0				
479 944,0	6 893 041,5	479 944,9	6 893 042,9	9,2	
479 948,7	6 887 495,5				
479 951,4	6 887 530,1				
479 961,7	6 892 848,0				
479 961,8	6 893 047,6	479 961,5	6 893 045,7	7,3	
479 966,1	6 893 867,2	479 964,8	6 893 867,7	6,7	
479 969,1	6 893 477,7	479 968,5	6 893 479,9	7,7	
479 973,4	6 892 631,6				
479 974,7	6 892 677,2				
479 979,1	6 892 994,2				
479 980,9	6 893 279,2	479 979,7	6 893 279,9	7,0	
479 984,9	6 894 176,3				
479 996,9	6 893 401,8				

The photos are located on NR's file system at J:\pro\CultSearcher\data\photos\Lesja_2015_11_01\ .

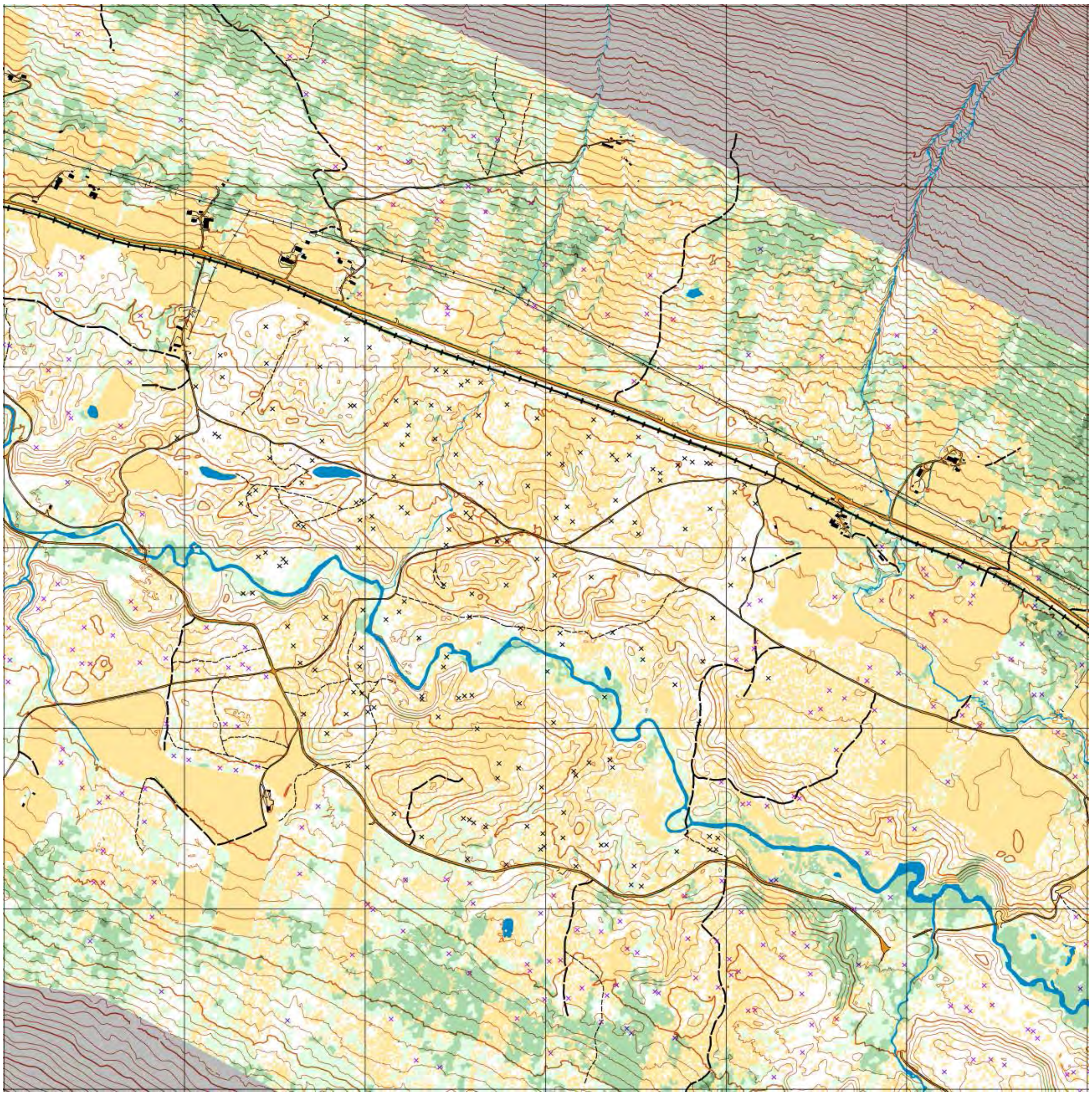

Figure 39. The 3×3 km² area at Sandom. Small black '×' = charcoal kiln with field verification. Small purple '×' = charcoal kiln mapped by visual interpretation.

Figure 40. Kiln no. 1, photo no. 6114.

Figure 41. Kiln no. 2, photo no. 6126.

Figure 42. Kiln no. 3, photo no. 6144.

Figure 43. Kiln no. 4, photo no. 6146.

Figure 44. Kiln no. 5, photo no. 6153.

Figure 45. Kiln no. 6, photo no. 6157.

Figure 46. Kiln no. 7, photo no. 6166.

Figure 47. Kiln no. 8, photo no. 6172.

Figure 48. Kiln no. 9, photo no. 6178.

Figure 49. Kiln no. 10, photo no. 6186.

Figure 50. Kiln no. 11, photos nos. 6192 and 6197.

Figure 51. Kiln no. 12, photo no. 6208.

Figure 52. Kiln no. 13, photo no. 6209.

Figure 53. Kiln no. 14, photo no. 6215.

Figure 54. Kiln no. 15, photo no. 6219.

Figure 55. Kiln no. 16, photos nos. 6225 and 6227.

Figure 56. Kiln no. 17, photo no. 6229.

Figure 57. Kiln no. 18, photo no. 6238.

Figure 58. Kiln no. 19, photo no. 6239.

Figure 59. Kiln no. 20, photo no. 6245.

Figure 60. Kiln no. 21, photo no. 6249

Figure 61. Kiln no. 22, photo no. 6254.

Figure 62. Kiln no. 23, photo no. 6265.

Figure 63. Kiln no. 24, photo no. 6269.

Figure 64. Kiln no. 25, photo no. 6271.

Figure 65. Kiln no. 26, photo no. 6275.

Figure 66. Kiln no. 27, photo no. 6280.

Figure 67. Kiln no. 28, photo no. 6287.

Figure 68. Kiln no. 29, photo no. 6296.

Figure 69. Kiln no. 30, photo no. 6300.

Figure 70. Kiln no. 31, photo no. 6305.

Figure 71. Kiln no. 32, photo no. 6309.

Figure 72. Kiln no. 33, photo no. 6315.

Figure 73. Kiln no. 34, photo no. 6316.

Figure 74. Kiln no. 35, photo no. 6326.

Figure 75. Kiln no. 36, photo no. 6338.

Figure 76. Kiln no. 37, photo no. 6339.

Figure 77. Kiln no. 38, photo no. 6344.

Figure 78. Kiln no. 39, photo no 6347.

Figure 79. Kiln no. 40, photo no. 6348.

Figure 80. Kiln no. 41, photo no. 6354.

Figure 81. Kiln no. 42, photo no. 6361.

Figure 82. Kiln no. 43, photo no. 6364.

Figure 83. Kiln no. 44, photo no. 6373.

Figure 84. Kiln no. 45, photo no. 6374.

Figure 85. Kiln no. 46, photo no. 6384.

Figure 86. Kiln no. 47, photo no. 6389.

Figure 87. Kiln no. 48, photo no. 6394.

Figure 88. Kiln no. 49, photo no. 6395.

Figure 89. Kiln no. 50, photo no. 6399.

Figure 90. Kiln no. 51, photos nos. 6401 and 6402.

Figure 91. Kiln no. 52, photo no. 6406.

Figure 92. Kiln no. 53, photo no. 6407.

Figure 93. Kiln no. 54, photo no. 6415.

Figure 94. Kiln no. 55, photo no. 6418.

Figure 95. Kiln no. 56, photo no. 6425.

Figure 96. Kiln no. 57, photo no. 6427.

Figure 97. Kiln no. 58, photo no. 6433.

Figure 98. Kiln no. 59, photo no. 6434.

Figure 99. Kiln no. 60, photo no. 6435.

Figure 100. Kiln no. 61, photo no. 6445.

Figure 101. Kiln no. 62, photos nos. 6447 and 6448.

Figure 102. Kiln no. 63, photo no. 6449.

Figure 103. Kiln no. 64, photo no. 6460.

Figure 104. Kiln no. 65, photo no. 6462.

Figure 105. Kiln no. 66, photo no. 6472.

Figure 106. Kiln no. 67, photos nos. 6479 and 6480.

Figure 107. Kiln no. 68, photo no. 6484.

Figure 108. Kiln no. 69, photo no. 6103.

Figure 109. Kiln no. 70, photo no. 6095.

Appendix B. Photo documentation of grave mounds at Vang, Oppdal

On 31 October 2015, a number of grave mounds were visited and photographed by NR in order to gain experience of their varying shapes, for the purpose of constructing a better semi-automatic method for grave mound detection.

Table 6. Photos of grave monuments at Vang, Oppdal.

Id	Time	Photos nos.	Comment
1	09:13	5841	
2	09:14	5842	Cairn, not detected.
3	09:15	5843-5844	Grave mound. Looted?
4	09:18	5845	
5	09:18	5846	
6	09:20	5847-5849	Elongated, not detecteed.
7	09:22	5850-5851	
8	09:24	5852	In a slope
several	09:27	5853	
8	09:27	5854	
1-7	09:29	5855-5858	From north of no. 8
9	09:32	5859-5861	
10	09:34	5862	With pit
11	09:36	5863	Elongated
12	09:39		False
13	09:41	5866-5867	Detected size smaller than true size
14	09:43	5868	In slope
15	09:44	5869-5871	
16	09:46	5872	Detected size smaller than true size
17	09:48	5873-5874	Large
18 (+17)	09:51	5875	
19 ++	09:52	5876-5878	
20	09:57	5879-5880	
21+22+23	09:59	5881	Photo taken from no. 24
24	10:00	5882	
21-23+25	10:01	5883	From west
30	10:22	5888	
31	10:23	5889	
32	10:26	5890-5892	
33	10:30	5893-5894	
34	10:33	5895-5896	Flat area
35	10:35	5897-5902	Detected but missing in official mapping
36	10:39	5903-5906	
37	10:42	5907-5908	
38	10:44	5909-5910	

Id	Time	Photos nos.	Comment
35	10:44	5911-5912	
40	10:46	5913-5914	
41	10:47	5915	
42	10:48	5916	
43	10:49	5917	
42+44+45	10:49	5918	
44	10:50	5919	
43	10:50	5920	
46	10:51	5921-5924	
47	10:52	5925	
48	10:53	5926	
49	10:55	5927-5928	
50-52	10:58	5930-5932	
53+54	11:02	5933	
54	11:03	5934	
55	11:04	5935-5937	
56	11:05	5938-5941	Many small heaps. Excavated?
57	11:07	5942-5944	
59	11:09	5945-5947	
58	11:10	5948-5950	
60	11:12	5951-5957	
61	11:14	5958-5963	Close to the river
62	11:18	5964	
63	11:21	5965-5966	Detected, but not in official mapping (?)
64	11:23	5967	
65	11:24	5968-5973	Elongated
66	11:26	5974-5975	
65	11:28	5976	
70	11:33	5977	
71	11:35	5978	
72	11:36	5979	
73	11:37	5980	
72	11:38	5981-5982	Steep on eastern side
74	11:40	5983	Flat
75	11:41	5984	
76	11:42	5985	
76+77	11:43	5986	
77	11:45	5987-5992	
78	11:47	5993-5998	
79	11:49	5999	
80	11:49	6000	
81	11:53	6001	
82	11:53	6002	
80	11:55	6003-6005	
83	11:58	6006	

Id	Time	Photos nos.	Comment
85	11:59	6008-6009	Elongated, incorrect location in official mapping
86	12:02	6010-6011	Pile of branches on flat area
87	12:03	6012	
88	12:05	6013	
89	12:06	6014-6015	On the path
90	12:07	6016:6018	
91	12:08	6019-6020	
92	12:12	6021	
93	12:13	6022	
94	12:13	6023	
95	12:13	6024	
93	12:15	6025	Bumpy
94	12:16	6026-6027	Bumpy
96	12:18	6028-6029	
97	12:22	6030	
98	12:26	6031-6032	
99	12:28	6033-6034	
100	12:29	6035-6037	
101	12:38	6038-6039	Flat. Wrong?
102	12:39	6040-6041	Elongated
103	12:40	6042	
104	12:41	6043-6044	
105	12:43	6045-6046	
106	12:45	6047	
107	12:47	6048	
108	12:48	6049	
109	12:50	6050-6051	
110	12:51	6052-6053	
111	12:52	6054	
112	12:53	6055-6057	Elongated
113	12:56	6058	Elongated
114	12:57	6059	Flat
115	13:00	6060-6062	Flat area, grave mound not visible.
116	13:04	6063	
117	13:05	6064	
117+118	13:05	6065	
119-122	13:09	6066-6067	
122+123	13:11	6068	
123	13:11	6069	
122	13:12	6070	
124	13:15	6071	
125	13:18	6072-6074	Elongated
126	13:20	6075-6076	Flat, weak circular ditch
127	13:22	6077	Pile of branches
128	13:23	6078-6079	Flat, weak circular ditch

Id	Time	Photos nos.	Comment
129	13:25	6080-6081	Bumpy, weak circular ditch
130+131	13:27	6082	
131	13:28	6083	
133	13:29	6084	Quite flat
132	13:30	6085	Difficult to see the exact boundary
134	13:32	6086	Bumpy
134+135	13:32	6087	135: elongated (seen from north of 134)
140	13:46	6088	Cairn
141	13:47	6089	Cairn
140	13:47	6090-6091	Withouth flash, with flash
141	13:48	6092, 6093	With flash, without flash

The photos are located on NR's file system at J:\pro\CultSearcher\data\photos\Oppdal_Vang_2015_10_31\ .

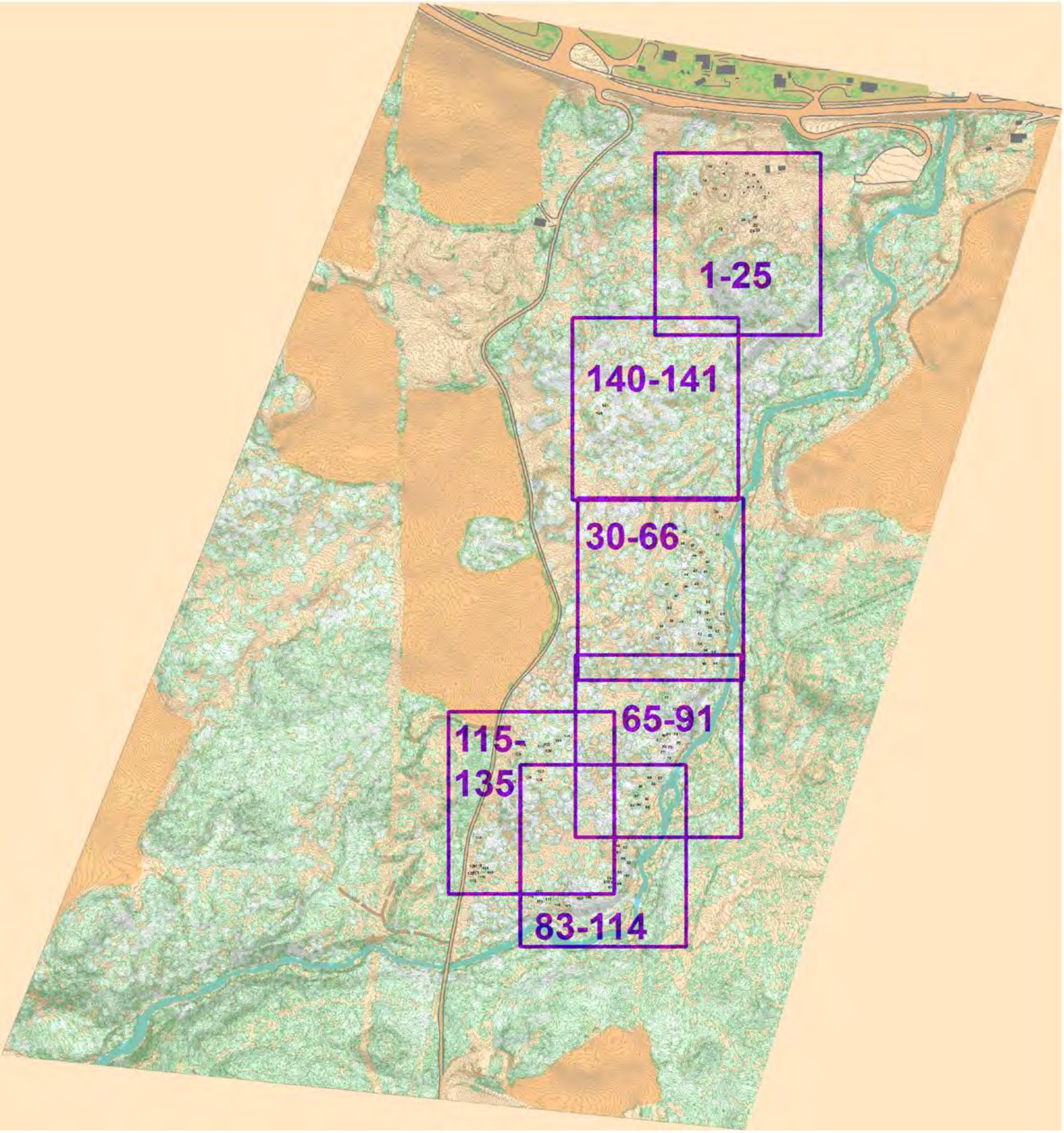

Figure 110. Overview map of the area covered by ALS data, with the extents of the six detailed maps in Figure 111, Figure 112 and Figure 113.

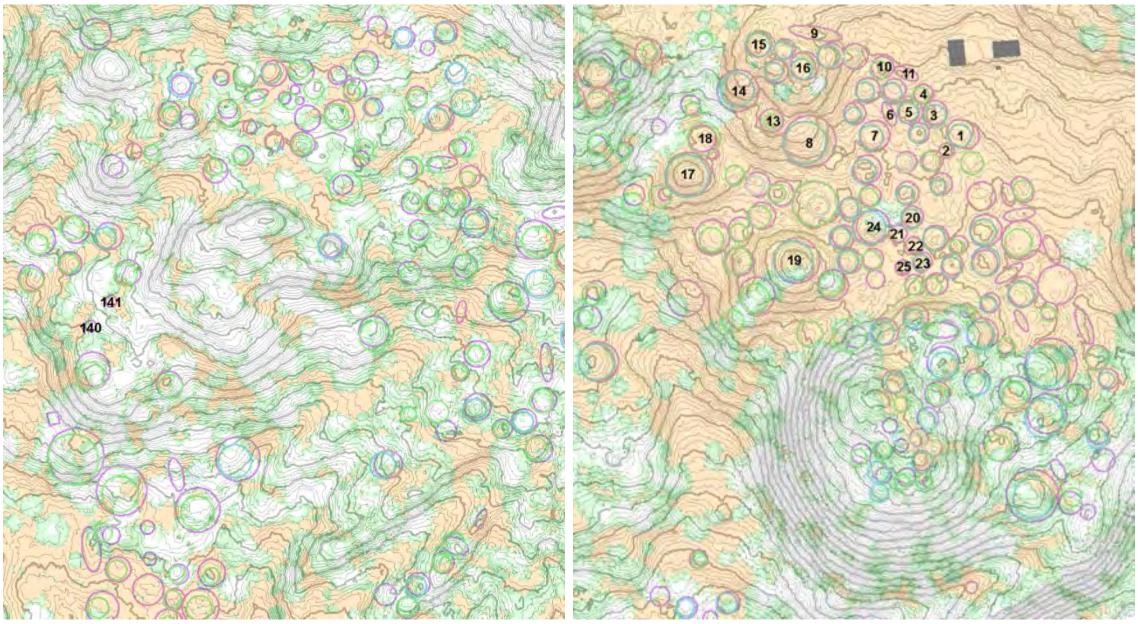

Figure 111. Left: two photographed grave cairns, labeled as nos. 140 and 141. Right: 25 photographed grave mounds, labeled as nos. 1-25.

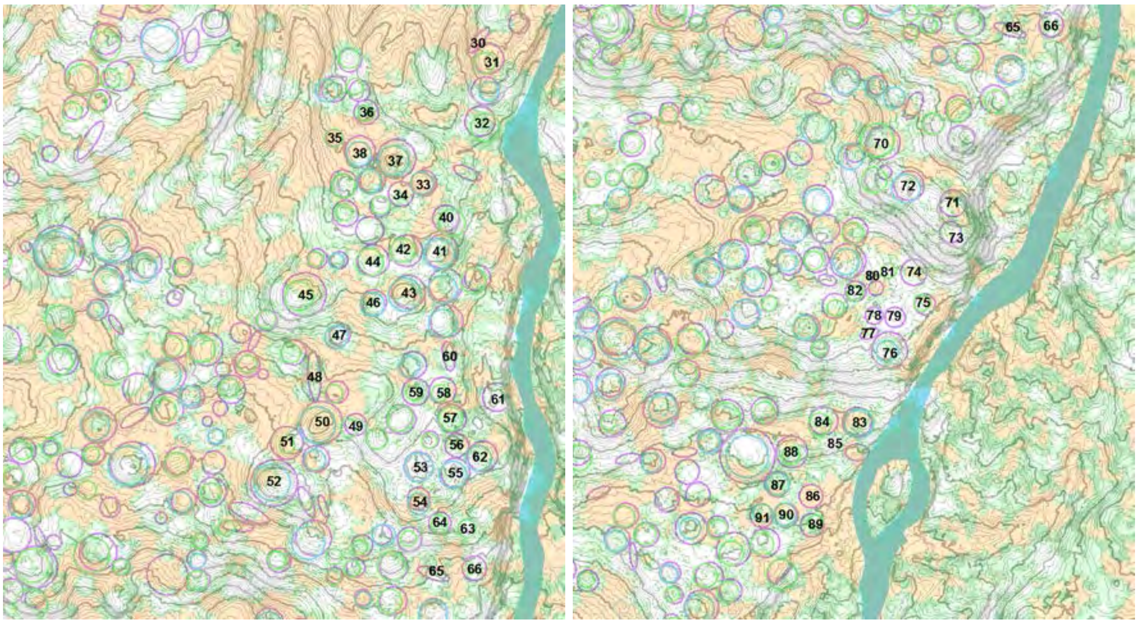

Figure 112. Left: 37 photographed grave mounds, labeled as nos. 30-66. Right: 27 photographed grave mounds, labeled as nos. 65-91.

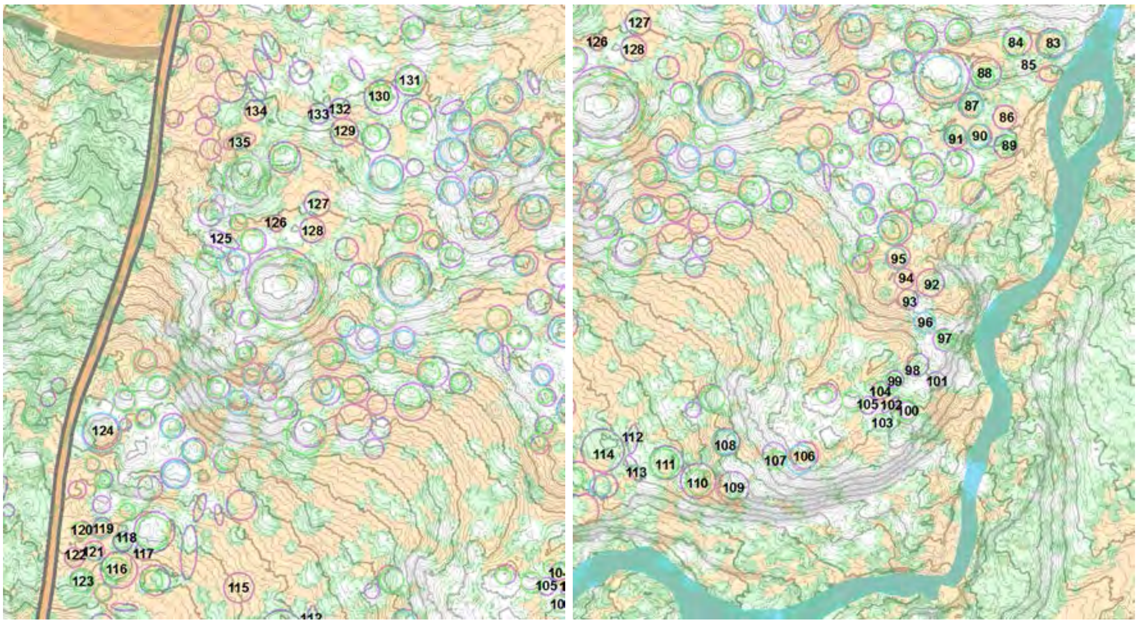

Figure 113. Left: 21 photographed grave mounds, labeled as nos 115-135. Right: 32 photographed grave mounds, labeled as nos. 83-114.

Figure 114. Grave mound no. 1, photo no. 5841.

Figure 115. Cairn no. 2, photo no. 5842.

Figure 116. Mound no. 3, photo no. 5843.

Figure 117. Mound no. 4, photo no. 5845.

Figure 118. Mound no. 5, photo no. 5846.

Figure 119. Mound no. 6, photo no. 5849.

Figure 120. Mound no. 7, photo no. 5851.

Figure 121. Mound no. 8, photos nos. 5852 and 5854.

Figure 122. Elongated mound no. 9 (in the middle of the photo) and mound no. 16 (on the hilltop in the upper center of the photo), photo no. 5860.

Figure 123. Mound no. 10 (with pit), photo no. 5862.

Figure 124. Elongated mound no.11 (in the middle of the photo), photo no. 5863.

Figure 125. Mound no. 13, photo no. 5867.

Figure 126. Mound no. 14, photo no. 5868.

Figure 127. Mound no. 15, photo no. 5871.

Figure 128. Mound no. 16, photo no. 5872.

Figure 129. Mounds nos. 17 (the taller, behind) and 18 (in front, in center right of the photo), photo no. 5874.

Figure 130. Grave mound no. 19 (the largest), photo no. 5877.

Figure 131. Grave mound no. 20, photo no. 5879.

Figure 132. Grave mounds nos. 21, 22 and 23, seen from no. 24; photo no. 5881.

Figure 133. Mound no. 24, photo no. 5882.

Figure 134. Mounds nos. 21, 22, 23 and 25, seen from the west, photo no. 5883.

Figure 135. Mound no. 30, photo no. 5888.

Figure 136. Mound no. 31, photo no. 5889.

Figure 137. Mound no. 32, photo no. 5892.

Figure 138. Mound no. 33, photo no. 5893.

Figure 139. Grave monument no. 34 (a flat area), photo no. 5896.

Figure 140. Mound no. 35, photo no. 3898. This mound is missing in the official mapping.

Figure 141. Mound no. 36, photo no. 5903.

Figure 142. Mound no. 37, photo no. 5908.

Figure 143. Mound no. 38, photo no. 5910.

Figure 144. Mound no. 40, photo no. 5914.

Figure 145. Mound no. 41, photo no. 5915.

Figure 146. Mound no. 42, photo no. 5916.

Figure 147. Mound no. 43, photo no. 5917.

Figure 148. Mounds nos. 42, 44 and 45 (the tallest), photo no. 5918.

Figure 149. Mound no. 44, photo no. 5919.

Figure 150. Mound no. 43, photo no. 5920.

Figure 151. Mound no. 46, photo no. 5921.

Figure 152. Mound no. 47, photo no. 5925.

Figure 153. Mound no. 48, photo no. 5926.

Figure 154. Mound no. 49, photo no. 5928.

Figure 155. Mounds nos. 50 (center), 51 (center right, behind no. 50) and 52 (tallest, behind no. 51), photo no. 5932.

Figure 156. Mounds nos. 53+54, photo no. 5933.

Figure 157. Mound no. 54, photo no. 5934.

Figure 158. Mound no. 55, photo no. 5936.

Figure 159. Mound no. 58, photo no. 5938.

Figure 160. Mound no. 57, photo no. 5942.

Figure 161. Mound no. 59, photo no. 5945.

Figure 162. Mound no. 58, photo no. 5948.

Figure 163. Mound no. 60, photo no. 5956.

Figure 164. Mound no. 61, photo no. 5961.

Figure 165. Mound no. 62, photo no. 5964.

Figure 166. Mound no. 63, photo no. 5966. This mound was detected but is missing in the official mapping.

Figure 167. Mound no. 64, photo no. 5967.

Figure 168. Mound no. 65, photo no. 5971.

Figure 169. Mound no. 66, photo no. 5975.

Figure 170. Mound no. 65, photo no. 5976.

Figure 171. Mound no. 70, photo no. 5977.

Figure 172. Mound no. 71, photo no. 5978.

Figure 173. Mound no. 72, photo no. 5979.

Figure 174. Mound no. 73, photo no. 5980.

Figure 175. Mound no. 72, photo no. 5982.

Figure 176. Mound no. 74, photo no. 5983.

Figure 177. Mound no. 75, photo no. 5984.

Figure 178. Mound no. 76, photo no. 5985.

Figure 179. Mounds nos. 76 and 77, photo no. 5986.

Figure 180. Mound no. 77, photo no. 5991.

Figure 181. Mound no. 78, photo no. 5998.

Figure 182. Mound no. 79, photo no. 5999.

Figure 183. Mound no. 80, photo no. 6000.

Figure 184. Mound no. 81, photo no. 6001.

Figure 185. Mound no. 82, photo no. 6002.

Figure 186. Mound no. 80, photo no. 6004.

Figure 187. Mound no. 83, photo no. 6006.

Figure 188. Mound no. 84, photo no. 6007.

Figure 189. Elongated mound no. 85, photo no. 6009.

Figure 190. Mound no. 86 (a pile of branches on a flat area), photo no. 6010.

Figure 191. Mound no. 87, photo no. 6012.

Figure 192. Mound no. 88, photo no. 6013.

Figure 193. Mound no. 89, photo no. 6014.

Figure 194. Mound no. 90, photo no. 6018.

Figure 195. Mound no. 91, photo no. 6019.

Figure 196. Mound no. 92, photo no. 6021.

Figure 197. Mound no. 93, photo no. 6022.

Figure 198. Mound no. 94, photo no. 6023.

Figure 199. Mound no. 95, photo no. 6024.

Figure 200. Mound no. 93, photo no. 6025.

Figure 201. Mound no. 94, photo no. 6026.

Figure 202. Mound no. 96, photo no. 6028.

Figure 203. Mound no. 97, photo no. 6030.

Figure 204. Mound no. 98, photo no. 6032.

Figure 205. Mound no. 99, photo no. 6033.

Figure 206. Mound no. 100, photo no. 6036.

Figure 207. Mound no. 101, photo no. 6039.

Figure 208. Elongated mound no. 102, photo no. 6041.

Figure 209. Mound no. 103, photo no. 6042.

Figure 210. Mound no. 104, photo no. 6044.

Figure 211. Mound no. 105, photo no. 6045.

Figure 212. Mound no. 106, photo no. 6047.

Figure 213. Mound no. 107, photo no. 6048.

Figure 214. Mound no. 109, photo no. 6051.

Figure 215. Mound no. 110, photo no. 6053.

Figure 216. Mound no. 111, photo no. 6054.

Figure 217. Elongated mound no. 112, photo no. 6056.

Figure 218. Elongated mound no. 113, photo no. 6058.

Figure 219. Mound no. 114, photo no. 6059.

Figure 220. Grave monument no. 115 (flat area), photo no. 6060.

Figure 221. Mound no. 116, photo no. 6063.

Figure 222. Mound no. 117, photo no. 6064.

Figure 223. Mounds nos. 117 and 118, photo no. 6065.

Figure 224. Mounds nos. 119-122, photo no. 6067.

Figure 225. Mounds nos. 122 and 123, photo no. 6068.

Figure 226. Mound no. 123, photo no. 6069.

Figure 227. Mound no. 122, photo no. 6070.

Figure 228. Mound no. 124, photo no. 6071.

Figure 229. Mound no. 125, photo no. 6074.

Figure 230. Mound no. 126, photo no. 6075.

Figure 231. Mound no.127 (a pile of branches), photo no. 6077.

Figure 232. Mound no. 128, photo no. 6079.

Figure 233. Mound no. 129, photo no. 6080.

Figure 234. Mounds nos. 130 (center) and 131 (behind), photo no. 6082.

Figure 235, Mound no 131, photo no. 6083.

Figure 236. Mound no. 133, photo no. 6084.

Figure 237. Mound no. 132, photo no. 6085.

Figure 238. Mound no. 134, photo no. 6086.

Figure 239. Mounds nos. 134 (bumpy, in front) and 135 (elongated, in the upper center behind), photo no. 6087.

Figure 240. Cairn no. 140, photo no. 6090.

Figure 241. Cairn no. 141, photo no. 6093.