Locating property boundaries by use of low-cost technology and available public datasets

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Key words: cadastre, surveying, boundary marks, low-cost technology, fit-for-purpose land administration.

SUMMARY

This paper describes the use of low-cost technology for location of property boundaries in Norway. The Norwegian cadastral map is of poor quality in many areas. Information about boundaries and parcel identifications can be incorrect or missing. The nationwide cadastral database (with cadastre-map) was introduced following the cadastral law in 2010. In most countries with German Style cadastre, a cadastral surveying procedure legally defines the boundary. In Norway this is not the case! In Norway, even if a boundary is recently surveyed, the cadastral survey does not give guarantee that it is the correct and the legal boundary that is surveyed. This has the consequences that multiple boundary descriptions can be presented and get legal force, when uncertainty and disputes arise regarding the location of a boundary. All kinds of boundary descriptions and maps can be presented as evidence to court in boundary disputes. The Norwegian cadastral surveyor has no formal authority to determine the location of a legal property boundary. The role is to be an advisor or mediator between the parties when the boundary is unclear, and hopefully contribute to a clarification. In the Norwegian surveying procedure over existing boundaries, the landowners themselves play the central role. Thus, it is important to have tools that are fit-for-purpose to efficiently communicate with the landowners. This article presents a study investigating methods for making cadastral information available to landowners so that missing boundary point/monuments can be found and land parcels properly registered for land administration purposes. This study shows that the use of historic orthoimages in combination with modern DTM/DSM and imagery greatly supports the process of georeferencing old cadastral maps, and the identification of features defining the boundaries for land parcels. This paper also suggest that the concept of fit-for purpose land administration should be explored further as it is very much suited for the situation in Norway. Appropriate measures should be taken to simplify the regulations and procedures for establishing a recognized cadastral map fit for its purpose.

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1. INTRODUCTION

The technological development has over the last decades led to development of low-cost software and hardware tools that can be used by professional and non-professional users – for example the individual landowner, to examine and survey the boundaries of their land.

Students and teachers from Western Norway University of Applied Sciences in Bergen have for 3 years carried out field exercises in cadastral surveys in Northern Norway, in the municipalities of Røst and Værøy, and methods for georeferencing of maps and boundary descriptions for localization of boundary marks and reconstruction of property boundaries have been tested. QGIS on mobile phones combined with georeferenced land consolidation maps and DTM/DSM and historical orthophotos have proved efficient. In the paper status and methods for field exercises and georeferencing and location of boundary marks by use of QGIS are described and evaluated. All figures in the paper are based on publicly available map data from the portals www.geonorge.no and www.norgeibilder,no, and publicly available digitized historical land consolidation maps from the archive of the Land Consolidation Courts at the portal https://wcarkiv.domstol.no/wcarkiv/kommunelist.wc?ID. Land consolidation maps are also available at the portal www.arkivverket.no. These portals are governmental portals.

1.1 The cadastral map – short historical background

The cadastral map in Norway is of varying quality and has poor coverage in some areas. The poor quality can be explained by historical reasons and the way the cadastral map has been established. The first economic mapping project in Norway started in 1804-05 when Norway was in union with Denmark but was stopped in 1815 when Norway came in union with Sweden. Cadastral surveying and mapping when land was subdivided, was not introduced in rural areas in Norway until 1980, and consequently a land surveying profession did not develop in rural Norway. Laymen should continue to describe boundaries when land was subdivided.

While a professional land surveying profession did not develop, the land consolidation system in Norway, what is today the land consolidation courts (LCC), were established in 1859, and should by their employed surveyors produce large volumes of maps, showing boundaries prior to and after the land consolidation process, especially around 1900. Despite several initiatives to combine the work of the LCC and the Norwegian Mapping Authority (NMA) to introduce economic mapping and cadastral surveying especially in the beginning of 1900s, it was not until around 1960 that economic mapping and mapping of property boundaries was introduced in rural areas in Norway, and then by photogrammetric mapping methods and organized at county level.

In cities and towns precise cadastral surveying developed after individual initiatives.

The quality of the economic mapping was varying. The lay-men system did not have the competence to update the economic maps, and in 1980 precise cadastral surveying and mapping was introduced also in rural municipalities, as a monopoly task, but with no system of governmental authorization of the surveyor, and no authority to determine the legal boundary. Digitization started in the mid-1980s, also with varying procedures and quality. In the mid-1990s a law commission was established on the background of the quality problems. Measures to improve the system was proposed, the most important were to introduce private authorized surveyors (should not be implemented) and establish a nationwide and homogeneous cadastral map (implemented).

A nationwide cadastre comprising a cadastral map was established and introduced in 2010. The new cadastral map was based on different sources, the main source in rural areas was the economic maps, while title plots was the main source in cities and town. The map was published on the web, available for all (zoom in and have a look: www.seeiendom.no) . However, since the implementation in 2010, it has become clear that the quality is not satisfying in many areas. There is an obvious need for updating and corrections of the cadastral map, and appropriate routines and resources for correcting the map are insufficient. For details about the cadastral development in Norway, see Mjøs (2020).

The shortcomings of the cadastral map when it comes to quality, are well documented (Røsnes, 2021). In Norway the cadastral surveyor does not have the authority to legally determine the boundary between neighbors, only what shall be registered. Determination of an existing property boundary is a private matter, until it comes to registration, and following the cadastral law, correction of the cadastral map need involvement from the landowners. When it comes to correcting errors, for example if the coordinates of a boundary point that has been determined in a previous cadastral survey is altered, the actual landowners must be notified, and if the correction of more than 10 cm, following the cadastral bylaws § 36 (3), a new cadastral certificate must be issued.

1.2 Crowd sourcing – a relevant tool for quality improvement?

In the award letter of 2021, the Ministry of Local Government and Regional Development imposed the NMA the following task: "Investigate the possibility of a solution where the parties themselves can easily register and control property boundaries". This order was a follow-up of the future scenario discussed in a proposal from the Ministry to Stortinget (the Norwegian Parliament) in 2016 (Ministry of Local Government and Regional Development, 2016, chapter 3.5). The order was followed up by the NMA by establishing a project *Crowdsourcing of property boundaries* at the end of April 2021 with the goal to assess whether the quality improvement of property boundaries in the cadastral map can be done with simple tools by the Norwegian landowners themselves. The project submitted their report to the Ministry by December 30, 2021 (Norwegian Mapping Authority, 2021). In their report the project group stated that ”the technological development in society, as well as section 27 of the Cadastral Act, opens for the landowners to agree on existing boundaries and register their boundaries in the cadastre. This gives reason to consider a user-based solution. It is assumed that using a standard smart phone will be the most user-friendly solution that will make it easy for landowners to be able to survey and register their boundaries by themselves. This has thus been set as a target for the work, on the condition that the survey fulfils the quality requirements set for boundary information in the cadastre.” (Norwegian Mapping Authority, 2021 p. 2).

Crowdsourcing by use of smartphones as a method for improving the quality of land administration by involving non-professionals was presented more than a decade ago, in a visionary paper by Robin McLaren held at the Innsbruck conference 2011. In his paper he identified ”land administration as an area where this crowdsourced supported partnership could make a significant difference to levels of security of tenure around the world.” (McLaren, 2011).

In 2014 the joint FIG / World Bank Fit-For-Purpose Land Administration publication was published. Fit-for-purpose Land Administration (FFPLA) means that land administration should be designed to meet the needs of the people and their relationship to land, rather than meeting requirements imposed through rigid regulations and demands for accurate spatial data (Enemark et.al. (2014).

Students and teachers at the Western Norway University have during their field work in cadastral surveying, amongst other issues, for three years been focusing on simplified methods following FFPLA principles for updating of the cadastral map. One topic has been the appropriateness of QGIS (by the QField plug-in), free public geographical data and georeferenced land consolidation maps on Smartphones to find and identify boundary marks in the field. The goal has been to test the appropriateness of this tool in the future management of the cadastral map in Norway, as a simple tool handled at local level by the landowners themselves.

QGIS is a free and open-source GIS system (www.qgis.org). QField is a plugin in QGIS that gives the user the possibility to export a QGIS project to a mobile device where QField is

installed. QField gives the user the possibility to study terrain, position and different layers of maps at the same time, and registerer and edit information in the field, based on the GPS positioning of the mobile device.

1.3 Why are the old land consolidation maps important?

The land consolidation maps (together with the written protocol from the land consolidation case) were the basis for, and also the basic documentation of, a thorough and normally long-lasting process where the landowners involved heavily in the rearrangement of their land. This contrary to the ordinary and simple land subdivision system, conducted by laymen, resulting in boundary descriptions but with no mapping. Consequently, the boundaries established and marked in a land consolidation, has strong confidence among the landowners even after a century (even if also these boundaries in principle can be subject to private changes following the freedom of contract). It can therefore be of utmost importance to find and identify the boundary markers set out by the land consolidation. These boundaries define basic elements for subsequent land subdivisions. Land consolidation maps are digitized and made publicly available (land consolidation maps 1859 – 1988, County of Hordaland, are accessible here: https://media.digitalarkivet.no/view/58619/1?indexing). By 2021 the archives of The Courts of Norway showed that it was recorded 77858 land consolidation maps produced prior to the existing land consolidation act was implemented in 2016 (M. Strand, personal communication, May 2, 2023).

2. CASE STUDIES

In this section, several cases are presented and discussed. We argue that applications like Qfield with supporting layers and datasets is a relevant tool for landowners to locate boundary monuments and features describing land parcels.

2.1 Case Røst

In the period 2020-2022, the Western Norway University of Applied Sciences conducted field work to explore simplified methods for updating the Norwegian cadastral map. The study has been conducted in the municipalities Værøy and Røst, (the western isles of the Lofoten-archipelago). The project was a joint venture between the cadastral authorities at municipality level, the County Governor of Nordland, and the County Surveyors office of the Norwegian Mapping Authority (NMA). Available datasets were integrated in a QGIS-project and exported as field data in the application QField as a tool for locating boundary-monuments at Røst.

The island of Røst is a small municipality in Nordland county in Norway, west in the Lofoten-archipelago. The municipality is very small and is essentially a large fishing village centered

around Røstlandet (From Wikipedia https://en.wikipedia.org/wiki/R%C3%B8st). The population in Røst was 475 persons in 2021 and is decreasing.

As described in earlier section of this paper, today's digital cadastral map in Norway is the result of several stages of registration. At least four milestones can be indicated for the island of Røst:

- Stage 1 - Retrieval of old maps/information from Land Consolidation Court (LCC) procedures. In the case for Røst, a major operation resulted in four detailed maps in 1959. Even maps from the late 1880's exist for the island. In addition to the maps – protocols with boundary descriptions gives a very good documentation of the parcels. (Solid involvement of landowners).
- Stage 2 – Photogrammetric (economic) mapping was initiated at Røst in 1984. Photos and map-sheets in scale 1:5000 were produced. (Partly involvement from landowners). A WMS-service of the 1984 imagery was designed as part of this project. It is now available in www.norgeibilder.no.
- Stage 3 – Digitization of the map-sheets to produce **one** digital cadastral database of the municipality. In this process the plan for Røst was to digitize/fit in the old LCC-maps rather than initiate a full procedure with photogrammetric mapping and validation. (The digitalization was performed without significant involvement of landowners). Unfortunately for Røst, stage 3 led to some set-back. The procedures of digitization of LCC-maps and other digital registration partly failed or were not performed according to standards. See examples below in the areas Hammer and Grimsøya.
- Stage 4 – The now digitized cadastral map was during the 1980s and 90s gradually updated. (Single-case updates of parcels in the digital cadastral database based on input from landowners). As preparation for the new cadastral act (enforced 2010) – all datasets were around 2006 transformed into the new spatial reference system EUREF89. This was a process without significant involvement of landowners.

In the late 1980's the effort to create a digital database started in Nordland. For Røst - the four LCC maps of 1952 of mainland Røst, were put together and digitized. Additionally, some of the information from the map-sheets from the photogrammetric mapping (1984) was also digitized. During the field courses in cadastral surveying at Western Norway University of Applied Sciences in Bergen, field surveys has been performed in several test-areas at Røst. This paper will focus on the findings of these field surveys in the areas Hammer, Grimsøya, Marka and Klakk.

*Figure 1. Above ae the four land consolidation maps from1952. Indicated i blue are the test study areas: In the west **Grimsøya**, in center the area **Klakk**. In east the **Marka** and **Hammer** area. Source: www.geonorge.no and https://wcarkiv.domstol.no/wcarkiv/kommunelist.wc?ID.*

Study-area Hammer.

In a digitalization process, errors may be introduced in datasets. In this case it seems that a minor overlap in the center, (where the corners of the map-sheets meet), have caused a shift in the digitized dataset. During our fieldwork in the area Hammer – such a shift was identified and documented to be in the range of +/- 6m.

The shift/artefacts caused in the digitizing process is illustrated in the examples from the Hammer-area. Note in particular the registered lines along the existing stone-fences/physical boundary-features:

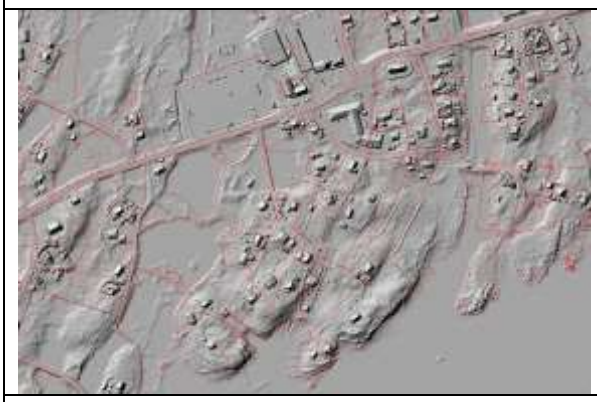
Area Hammer with section of the original LCC-map from 1952.	Area Hammer displaying the map produced by photogrametric mapping 1984 (national programme for economic mapping). In the background WMS Norge i bilder -prosjekt with historic imagery. Note that in 1984 – the mapped features corresponds with the detail in the imagery (NO shift!)
	
The national Digital Surface Model also serves as a very useful dataset for analysis and practical field-work. Here we see the cadastral situation in Hammer area in 2020, prior to project. Digitized and transformed data, (red lines), indicates **a shift in the range of +/- 6meters** compared to the boundaries (i.e. stone-fences).	In addition to historic images – we used the latest imagery for reference. (WMS with 2022 imagery) Red lines indicate the cadastral situation in 2020, prior to project.

Figure 2. In the area Hammer the lines/parcels from the original LCC-maps and economic map-sheets have been partly distorted in the digitalization-process (stage 3).
Source: www.geonorge.no, https://wcarkiv.domstol.no/wcarkiv/kommunelist.wc?ID and www.norgeibilder.no.

Study-area Grimsøya.

At test-area Grimsøya the main problem was not shifts or possible artifacts due to of transformations. In this area the LCC maps from 1952 had been outdatet and mapping with photogrammetry was selected to capture new development in the area.
In 1984 the parcels were successfully identified in the imagery, verified in the field and captured in the maps in scale 1:5000. However, poor quality control led to details being ”lost” due to unsuccessful digitalization. The example of Grimsøya is depicted below.
Note the surveyors recording of boundary features in the images. The surveyor also produced a list of points with specific details about each boundary-point. Such details could be: the type of physical marking/monuments, offsets measured, reference to documents, the presence of landowners during the on-scene validation, the surveyors best judgements/assumptions (in case land-owners were not present for reference/proper validation). Below right we can see the resulting map sheet - produced in scale 1:5000 in 1984.

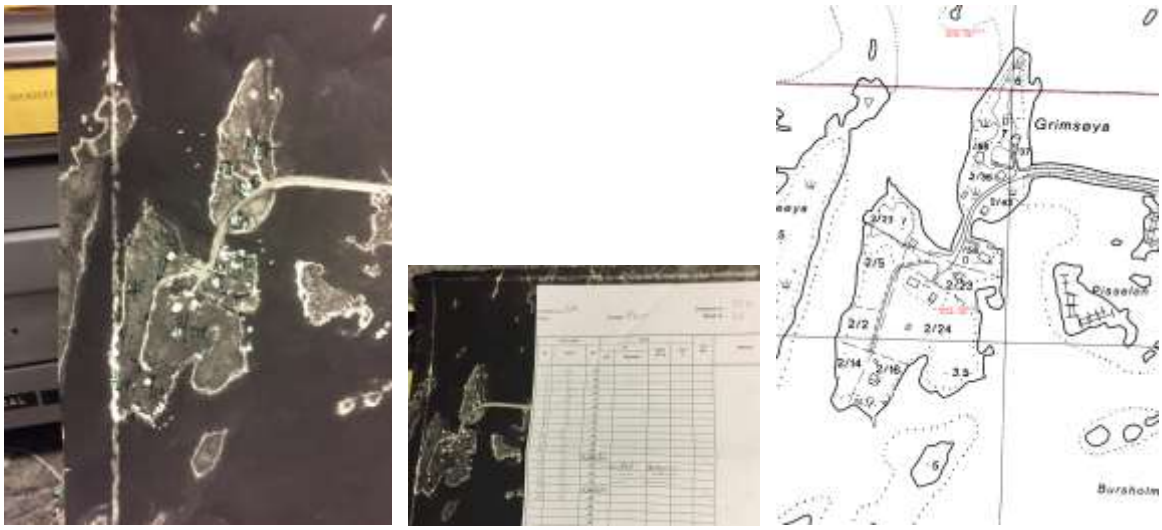


Figure 3. Documentation from the national economic mapping program - in the area Grimsøya in 1984. During the field survey/registration, the location of boundary-marks were identified on the ground together with the corresponding detail in the images. Points were registered, lines could be drawn and parcels with unique identifiers was indicated on the image/map. Source: www.geonorge.no and material retrieved from the archive at Regional office NMA Bodø Nordland.

As mentioned, quite a few of the parcels/boundaries that were successfully recorded in 1984 did not survive the digitalization-process that followed…

In figure 4 we can see the end-product of the 1984-mapping with registered land parcels. In center – red lines indicating the cadastral situation in 2020. Nearly 40 years later, in cooperation with landowners, we were able to restore the cadastral map at Grimsøya using simplified methods as depicted with blue lines in figure below-right.

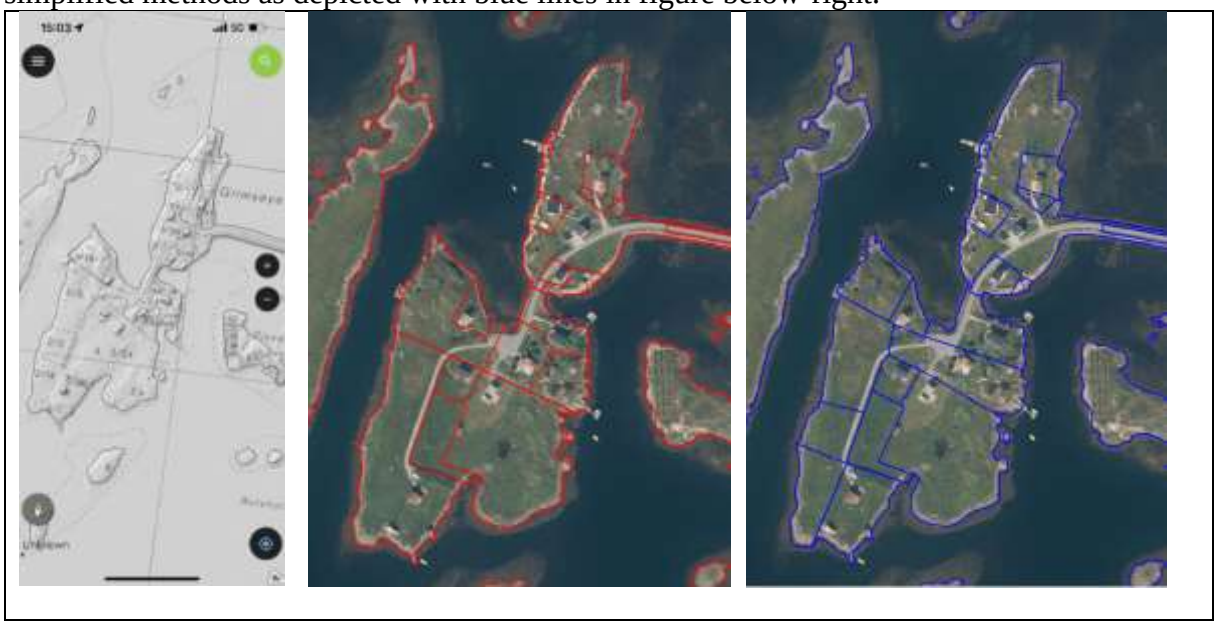


Figure 4. Above left we see the original map from from 1984 in use as a WMS-layer in the QField application. As the center-image above displays – the Digital Cadastral map of 2019 (red lines) does not include all the parcels from the 1984-

mapping. Above right, with blue lines, the restored cadastral map after performing field work coordinated with landowners. Source: www.geonorge.no and www.norgeibilder.no.

The 1st edition of the 1:5000 economic map is available as a WMS. Together with WMS with images of the original signaled boundary-points or georeferenced maps, they constitute a practical tool to locate old cadastral markers.

Study-area Klakk & Marka

To locate the physical monuments in the field, the georeferenced land consolidation map(s) proved adequate in most cases. For further reference, the LCC protocol of 1959 with detailed description of the boundaries was ordered from the LCC-archives – see extract of text in figure 5 below:

Grense nr. 90 går ut fra nedsatt stein (176 i grense nr. 88) med retning omtrent NV t. N 9,5 m til nedsatt stein (178), ny retning NO t. O 29,0 m til nedsatt stein (179).
Grense nr. 91 går ut fra nedsatt stein (179 i grense nr. 90) med retning Nt. V 34,2 m til borhull i berg (180) (triangelpunkt 4), videre med retning N t. O 3/4 O 119,0 m til kors i stein (181), 120,8 m til nedsatt stein (182), 64,5 m til kors i stein (183), 83,3 m til nedsatt stein (184), 36,9 m til borrhull i berg (185) (triangelpunkt 6), ny retning N 1/4 V 43,9 m til kors i stein (186) og videre (23,- m), ny retning omtrent ONO 38,5 m til kors i berg (187) og videre 6,7 m.
Grense nr. 92 går ut fra nedsatt stein (179 i grense nr. 90) med retning omtrent NO 20,0 m til kors i berg (188) og videre 0,7 m, ny retning omtrent SO 10,0 m til nedsatt stein (189).

Figure 5. Extract from the LCC-protocol describing the boundary lines and corresponding map-details. Note the description of Boundary no 91, with details about type of marking, point number, (ex No 184), distance from other points and indication of change in bearings/azimuth. Source: https://wcarkiv.domstol.no/wcarkiv/kommunelist.wc?ID

A tape measure (50m) became a handy tool to support the search for monuments along the boundary line in case vegetation shielded stones or markers. In the example above, point no 184 can be located as we have information about the distance 183-184 (83,3meters) and 184-185/VI (36,9 meters).

In figure 6 below, some of the screenshots from the QField mobile application is presented. Using QField, we could easily navigate close to the area where we expected to find monument no 184. The detail we searched for – a placed stone (main stone accompanied by two "stone-witnesses") was found within a few meters from the position indicated by the application.

Figure 6. Using the application Qfield on a mobile platform – we were able to find old boundary stones/markers in the Klakk area. Within a circle of 4 meters radius from the detail in the map/application, we were able to find most of the cadastral monuments in the area. Source: Screenshot Qfield and https://wcarkiv.domstol.no/wcarkiv/kommunelist.wc?ID. Photo: Per Ove Røkke.

The applications' main purpose is to quickly guide the user to an area where search for monuments in the field can be initiated. As long as the user can relate to the map or navigate by displayed terrain-features in the application, information about technical accuracies is in this study of minor importance. However, for control purposes, a verification of the mobile applications accuracy was made against the NMA trig-pillar H12T0041:

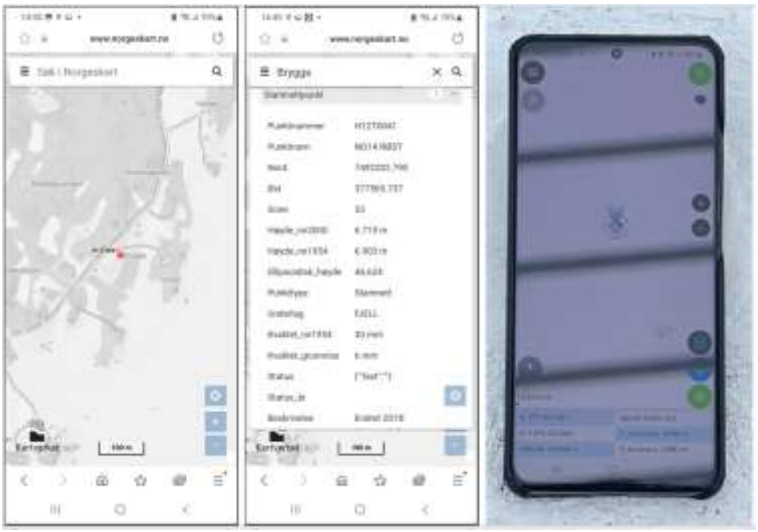


Figure 7. Test of the positioning from mobile application performed at The NMA pillar at Røst. Position recorded by the mobile application, has a shift of around 2 meters compared to "true value". Source: www.norgeskart.no and screenshots from Qfield.

First stage in any updates of our cadastral map will be to involve landowners and let them identify the existing boundaries. Applications like QField with supporting layers of information, can be of great aid to land-owners if needed. Images and records of the position of monuments, (when found), can be made by landowners in the field and reported to cadastral authorities so that cadastral maps can be completed and updated. Even QField-records with coarse accuracy, (in the range of a couple of meters), can be used to update the cadastral map.

Should parties need registration with improved accuracy – a special GNSS antenna can be connected to the mobile platform and QField will be able to record data with supporting correction services. In our case the NMA Centimeter Positioning Service CPOS was used. As part of the project, a test was performed at Røst on the 18th of August 2021. Using Trimble Catalyst GNSS with CPOS positioning support, 96 physical markers were recovered and measured with centimeters' precision:

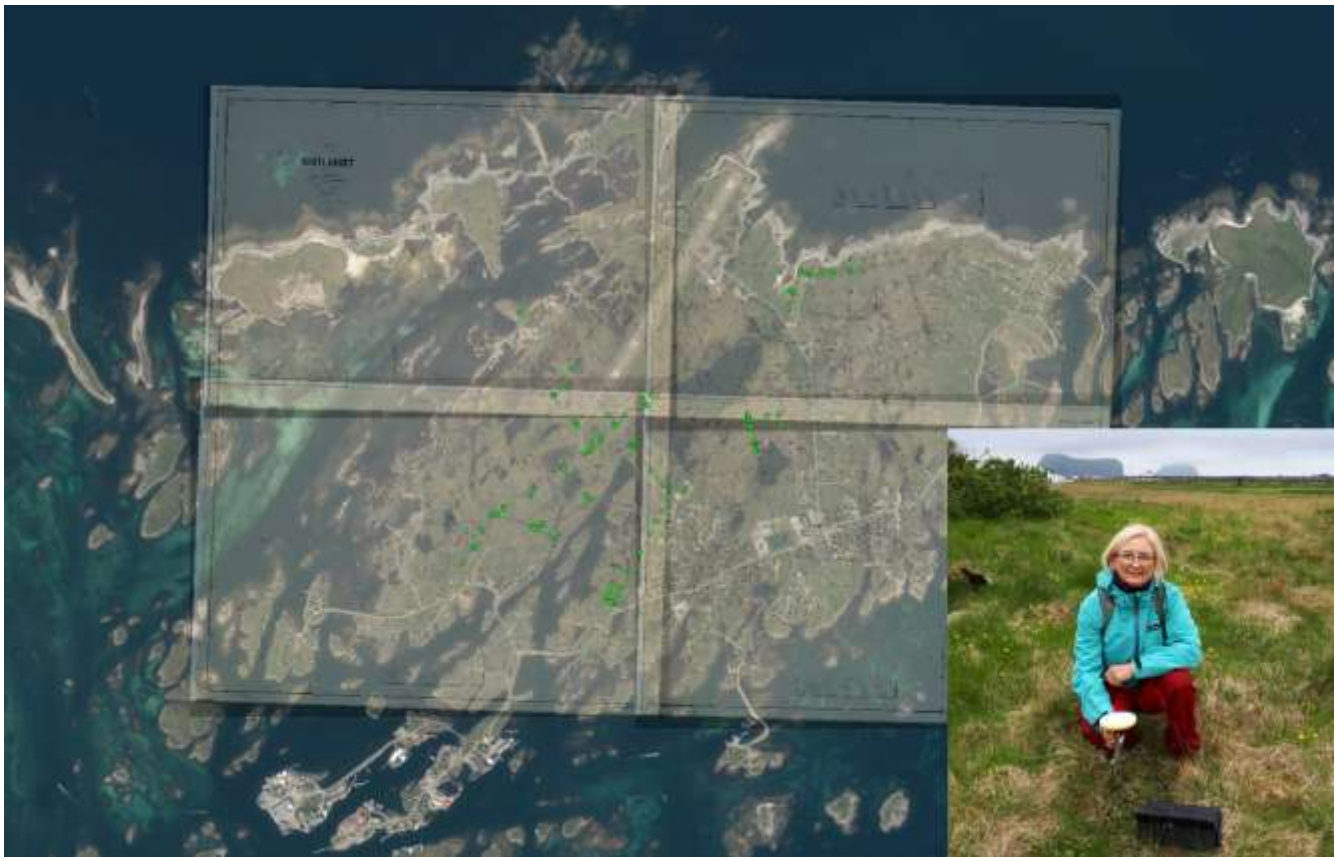


Figure 8. Test of mobile application including cm-GNSS services. Around 100 cadastral monuments were recovered and measured using Qfield-application. Even personnel not trained as a surveyor could perform registration without major

introduction. Source: www.norgeibilder.no and https://wcarkiv.domstol.no/wcarkiv/kommunelist.wc?ID. Photo: Per Ove Røkke.

As supporting layers in a mobile application, to assist the location of physical details in the field, we also explored the use of historic imagery and Digital Surface-models. Depicted in figure 9 below we can see how datasets were used in the Marka-area to support the search for physical boundary-details in the field.
Indicated with yellow circles, is the Boundary point no 678 from the LCC-map. This stone/marker was also identified and signaled as part of the photogrammetric mapping initiative in 1984 as we see in the red frame below.
WMS-services with historic imagery will give guidance to the area where physical markers can be found. Landowners that are familiar with the origin of their boundaries will be able to use such a WMS service to relocate boundary markers.
Similarly, as indicated below right – the Digital Surface Model can be used for reference.

Figure 9. Study area Marka with the use of different WMS-services with historic imagery and DSM to support operations. Source: www.geonorge.no, www.norgeibilder.no, https://wcarkiv.domstol.no/wcarkiv/kommunelist.wc?ID and screenshot from application Qfield.

The images from the photogrammetric mapping initiative, (economic mapping), and the resulting map sheets produced in scale 1:5000, provide the basis for most registration in the cadastral map we have today.
In addition to the images themselves, where the original signals can be identified, the NMA regional offices holds more detailed information of the registration.

The funding of our project has made the 1984-images for the municipalities Værøy and Røst available to the public as a WMS service. The remaining 39 municipalities of Nordland do not have such a service operational.

2.2 Case Alver

Alver is a medium-large municipality in Vestland county. It is a neighboring municipality to Bergen, the second largest city in Norway (https://en.wikipedia.org/wiki/Alver_(municipality)). The population was 29593 in 2022 and is increasing. The case presented is not far from the village of Bøvågen, and one of the authors is landowner. The land investigated was planted in the 1950 – 1960s. In 2022 the forest in the area (several properties) was logged by use of heavy logging machines. The boundary investigated was established by the land consolidation implemented in 1908 where the outfields, mainly marsh land, of the farm Villanger, previously mainly in joint ownership, was divided into individual parcels. This led to the forest planting. In this area there are no historical forestry traditions. In the case we are investigating if and how the boundary marks established in the land consolidation from 1908, can be found after logging by heavy forest machines.

The first edition of the economic maps (at the time Radøy municipality) was established in the early stage of economic mapping, by aerial photographs of 1961. In the area there is a rather good match between cadastral map, economic map and land consolidation map.

In the case we have investigated the line 1-2-3 shown in figure 10.

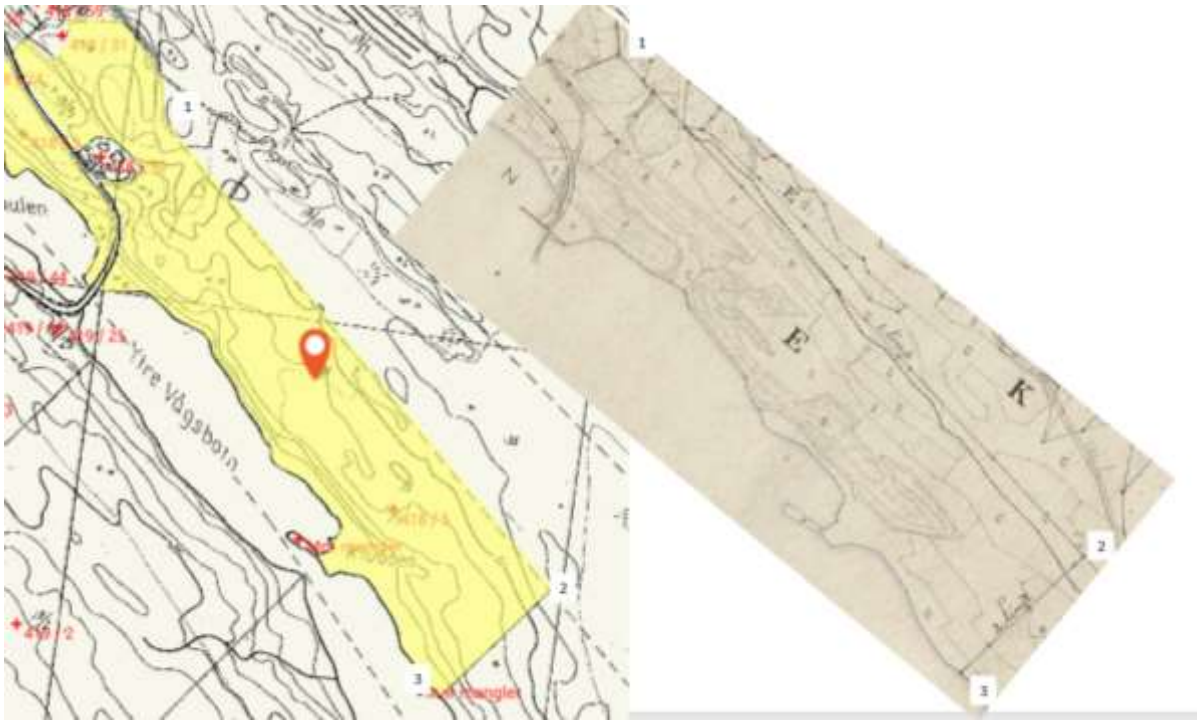


Figure 10. To the left we can see registration in the cadastral map with yellow color and the economic map as background. To the right the land consolidation map. In the land consolidaton map the boundary marks set out in the terrain are marked. The boundary line investigated is marked 1-2-3. Source: www.geonorge.no and https://wcarkiv.domstol.no/wcarkiv/kommunelist.wc?ID.

When we study the land consolidation map, we can see that there are 5 intermediate boundary markers between 1 and 2, and 2 intermediate markers between 2 and 3. See figure 2.

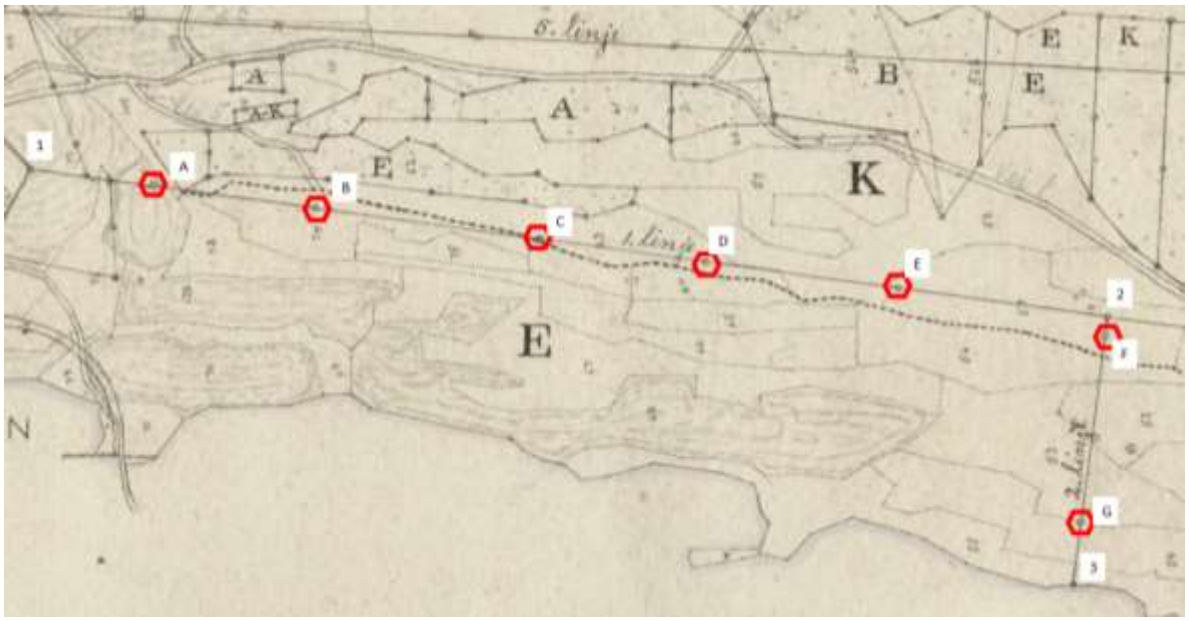


Figure 11. Section of the land consolidation map, showing the investigated boundary line. Points 1 - 3 are corner points, A - G are intermediate markers on the line between the corner points. Source: https://wcarkiv.domstol.no/wcarkiv/kommunelist.wc?ID.

None of these intermediate markers are marked in neither the economic map nor the cadastral map. We shall now describe how we have used QGIS and Qfield to search in the terrain for the points in figure 11.

The methodology used is :

Step 1: QGIS:

Establish a project.
Load background information: the topographic map and cadastral map.
Georeference the land consolidation map.
Export the project by the Qfield plugin.

Step 2: Qfield:

Import the QGIS project.

Step 3: Terrain:

Move to the actual area, walk to the position by use of Qfield and look for the boundary markers. They are normally within a distance of 3 – 5 meters.

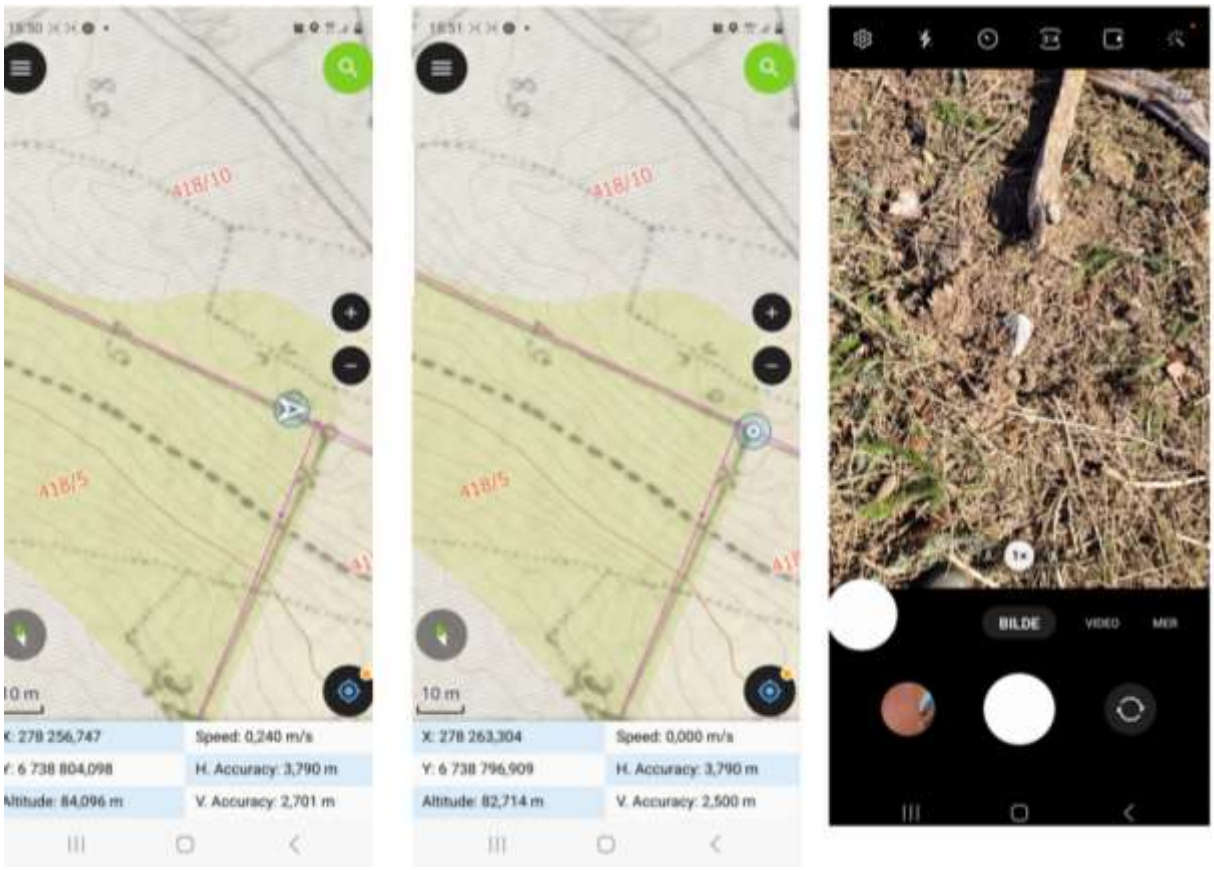


Figure 12. Moving to the boundary line and following in screen shot left. In the screen shot in the middle we have found the position of boundary mark 2. Picture to the right show the boundary stone found at the position Source: www.geonorge.no, https://wcarkiv.domstol.no/wcarkiv/kommunelist.wc?ID and screenshot Qfield. Photo: Leiv Bjarte Mjøs.

By this methodology we have searched all the positions, and the results are presented in table 1 below.

Boundary point	Type of boundary marker	Result
1	Boundary stone	Stone fence erected on position
A	Cross in solid rock	Stone fence erected on position
B	Boundary stone	Uncertain
C	Boundary stone	Not found, big tree at position
D	Boundary stone	Not found
E	Boundary stone	Found
2	Boundary stone	Found
F	Cross in solid rock	Stone on position, brought there by the landowners to mark the cross?
G	Boundary stone	Not found
3	Boundary stone	Found

Table 1 Results from search for boundary markers with Qfield

3. SUMMARY, CONCLUSIONS AND WAY FORWARD

The case studies shows that we can successfully identify old cadastral monuments in the field within a few meters from the initial point our application suggests.

Lessons learned from the study areas show that use of mobile phones, QGIS and Qfield and georeferenced historical imagery and land consolidation maps can be of significant value in the maintenance of the cadastral map in Norway. Cadastral authorities, as well as the landowners themselves can by using their mobile phone and available public data locate physical boundary marks in field in a more effective way. Manual interpretation of maps and boundary descriptions in a more traditional way could in fact be quite difficult. Presenting old maps and spatial reference to boundaries in a user-friendly format will add value to the data. Provided clear and practical guidelines, the available datasets can support landowners should they need to update the cadastral map. With coordinated effort and facilitation of a user-friendly service for cadastral update, it is likely that costs also can be reduced. Obviously, the time used to search for monuments will be significantly reduced!

However, it is of importance that the landowners can easily get access to information about how the cadastral system works and that the landowners themselves are responsible to secure their boundary marks, and how to use georeferenced material for this purpose.

What can we say about the way forward? If the quality of the cadastral map shall be improved, involvement from the landowners is needed. The concept of crowd sourcing and use of low-cost technology and free data is a way to achieve this. However, if such a methodology shall be of any use, NMA should take initiatives to georeferencing all historical land consolidation maps, aerial photographs from the economic mapping, and other relevant material, og making this material available for the landowners at for example the portals www.geonorge.no and www.norgeibilder.no. All archives at the NMA regional offices from the economic mapping must be preserved and digitized and made available for the public. An actual method for the massive activity of georeferencing can be crowd-sourcing, by inviting ”the crowd” to participate in the georeferencing, with support and control from NMA, before publishing the georeferenced material at the portal. Georeferencing by “the crowd” will probably make the search circle larger, but still acceptable for “the crowd” to search for their boundary marks. Automatic georeferencing based on using artificial intelligence (AI) could also be used as an alternative (Luft and Schiewe, 2021).

What also is advised to be considered, is developing tools that enables the landowner or his consultant to submit their findings to the cadastral authorities, pics, videos and coordinates, and to ensure successful implementation it is important that NMA gets in place information material that thoroughly clarifies for all parties involved - landowners and employees of the cadastral authority - what is the role of landowners and what is the role of the authorities

when it comes to the question of at property boundary. A good starting point might be tools already available at the portal https://www.rettikartet.no/. Finally, we recommend that the cadastral authorities develop further initiatives to simplify the formal procedures for correcting and updating the cadastral map, which now appears unnecessarily complicated and rigid. The fit-for-purpose land administration principles presented by FIG /The World Bank in 2014, will be a good basis for a future development.

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