Determine the Cadastral Borders by Natural Shapes Instead of Border Marks? Why Not?

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Keywords: Cadastre, Lidar, Orthophotos

SUMMARY

Finnish cadastral system is based to a Nordic variation of German system. Finnish cadaster's fundamental part is on the border marks placed to the field. The border marks are more relevant than cadastral maps or coordinates when determine the true location of the border although the borders are fixed on cadastral map.

Cadastral proceedings can be divided in two sections, the technical part and judicial part. Technical part includes the fieldwork, surveying and marking the border to the field. After the fieldwork the parcel is unambiguous to the new owner. The judicial part includes the cadastral meeting and registration of the proceeding.

The accuracy requirements to the border marks are 0.1 m -0.5 m depending the value of the land. These requirements are made by National Land Survey of Finland. Because of huge amount of the inaccurate border marks, accuracy worse than 0.5 m, the proceedings include a visiting to the field in any case. Sending a professional land surveyor to the field is expensive. Sometimes the surveying of the parcel is more expensive than the value of the parcel.

To reduce the costs of the field work the author of this paper tested different methods to determine new borders to the field and to cadastral map too. The demarcation of borders were made from orthophotos and lidar -data to the natural shapes such as ditches, roads, vegetation edges etc.

The results showed it is possible to determine new borders without going to the field with high accuracy and when using the combination of lidar -data and orthophotos the accuracy would be better.

As a conclusion the border determination without field work is possible to adapt as a part of the modern proceedings. This method is suitable to use on rural areas, where the land value is low and the need of accuracy is lower; of course when determining the border to the natural shapes the border is unambiguous on the field and less accurate on cadastral map only. The method needs changes to the legislation and to the land surveyor's attitude too.

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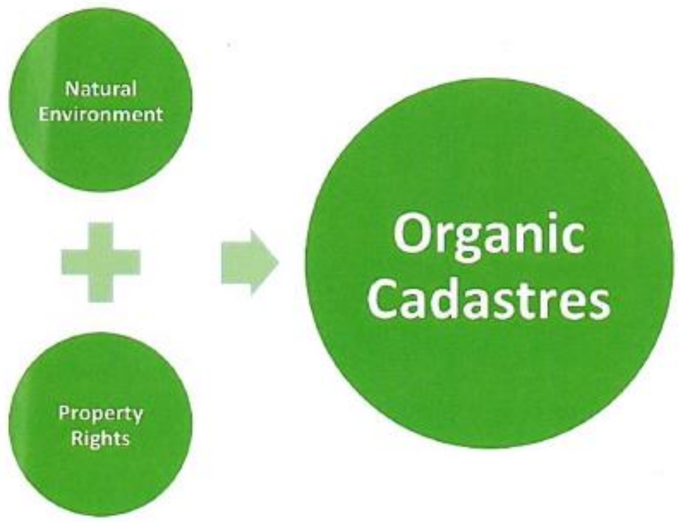
1. ORGANIC CADASTRE - FUZZY BORDERS

Bennet and van der Molen (2012) published an article about natural and sc. fuzzy borders in GIM Magazine. An organic cadastre is defined as a cadastre where the borders follow natural phenomena which are generally impossible to determine accurately. Those borders may also be changeable. These principles are shown in Figure 8.



The principles of green cadastre

Borders would not be straight lines on the map and on the ground; they would follow natural shapes and this approach would lend to more efficient land use.

Natural boundaries already exist in some cadastral systems. For example, in Finland a border is possible to determine by following the natural shape of e.g. a shoreline, ditch, or even the borders of different vegetation zones. Borders however will not follow the changes of natural shapes. This is shown in following, where the red lines are the present borders and the longest east-west border is determined by the 1931 shoreline. The shoreline has however since receded because of upthrust (at a rate of approximately 1 cm / annum) and the determined border and shoreline are no longer in same locations.

The results of upthrust in Hailuoto

Australian states use a similar approach to Finland, but the border follows the changes. For example, if the border is determined to the waterway but because of erosion the location of waterway changes, the border then follows the true location of the waterway. If the natural borders follow the phenomena of nature; although it changes, the cadastre and related data are not necessarily up-dated. In such cases, the land surveyor needs to input the new location of border to the cadastre.

Fuzzy borders are possible to determine in many ways, and this thesis introduces the most common methods: field surveys, ortho / satellite photos and the usage of images produced from Lidar data.

1.1 Ortho photos

An ortho photo is produced from aerial photos by correcting the errors caused by inclination and scale. The ortho image is an aerial photo map and you can correctly measure distances and areas from the ortho photo. The most common way to perform aerial photography is to install a digital aerial photo camera in an aeroplane. From one flight, it is possible to produce black and white, colour and infrared images. The frequency of these flights is 3–10 years in

Finland. The National Land Survey of Finland is using digital aerial photos to map and produce a height model. From the ortho photo it is also possible to orientate the image to form the background of a cadastral map, with the resolution of the image being approximately 0.5 m per pixel.

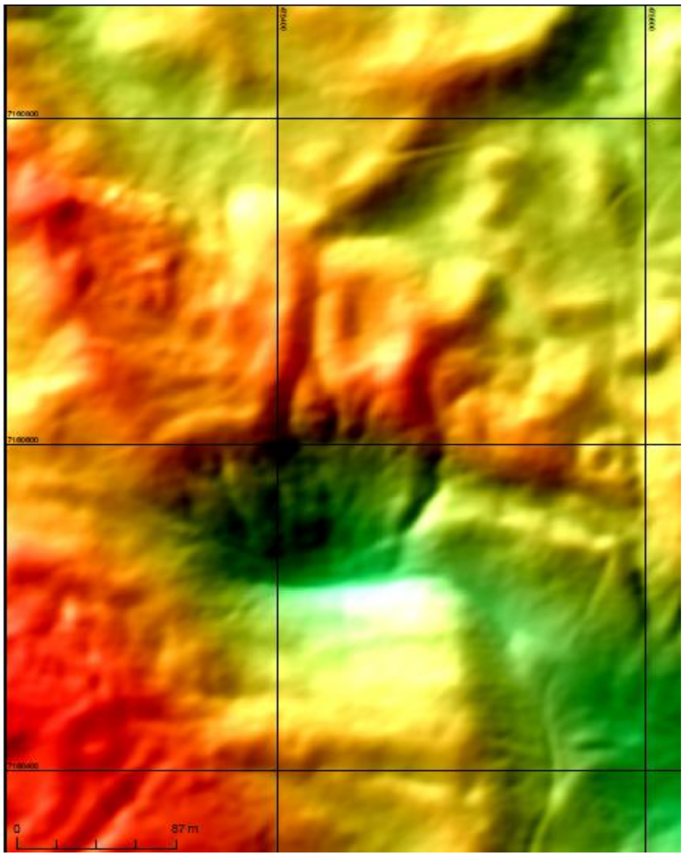
1.2 Light Detection and Ranging (Lidar)

Lidar is a remote sensing method which uses pulsed laser to measure distances between the target and sensor. The sensor sends a laser beam to the surface and when it reflects back it is possible to measure the range between the sensor and the surface. From the results it is possible to generate a 3D-model of the surface and everything above it.

Common platforms for a Lidar instrument are aeroplanes and helicopters and it is possible to cover broad areas in a short time. The Lidar instrument includes a laser, scanner and GNSS receiver to locate the exact location of Lidar instrument.

Lidar generates a digital 3D point cloud model from the measurement and the post-processing programmes can separate different structures of the surface, e.g. the terrain, vegetation, buildings etc. The National Land Survey of Finland has produced Lidar data since 2008 and it is mainly used to generate a height model. The accuracy of the data is approximately 0.3 metres in vertical and 0.6 metres in horizontal accuracy. In Finland, Lidar data is classed as open data, which you can download without charge.

From the point cloud model, you can generate a picture of the terrain with a diagonal hatch to show the differences in height. These images are also possible to orientate to the background of a cadastral map, in the same way as ortho photos. One application of Lidar images in cadastral surveys is to locate the position of roadways and possible easement. It is also used when a new right of way is established to an existing roadway and there are no field surveys conducted. Picture 3 shows the image produced from Lidar data and the heights of terrain are indicated with different colours.



Lidar image from Rokua National Park

1.3 Testing

To test the usability of fuzzy borders and their determination, a series of test ranges were established and measured using different methods. These results were then compared to the Finnish system.

In the present system, the borders are shown in the databases but there is still a link to the field. Using the coordinates downloaded from the database you can locate the border located in the field which is marked by markers on the ground level. Such coordinates however are not the primary demarcation when determining the location of former border, and physical markers in the field hold more precedence, likewise old cadastral maps of the area. In the Finnish system, the root of the cadastre is in the Base Land Consolidation, which took place from the late18th century to the 1960s. Coordinates have only been measured since the late 1980s.

In the Finnish cadastral map, almost every border mark has a coordinate, but the location accuracy of these border marks is inadequate. Also, due to the historical aspect there is still a lot of error in the demarcation of borders and parcels.

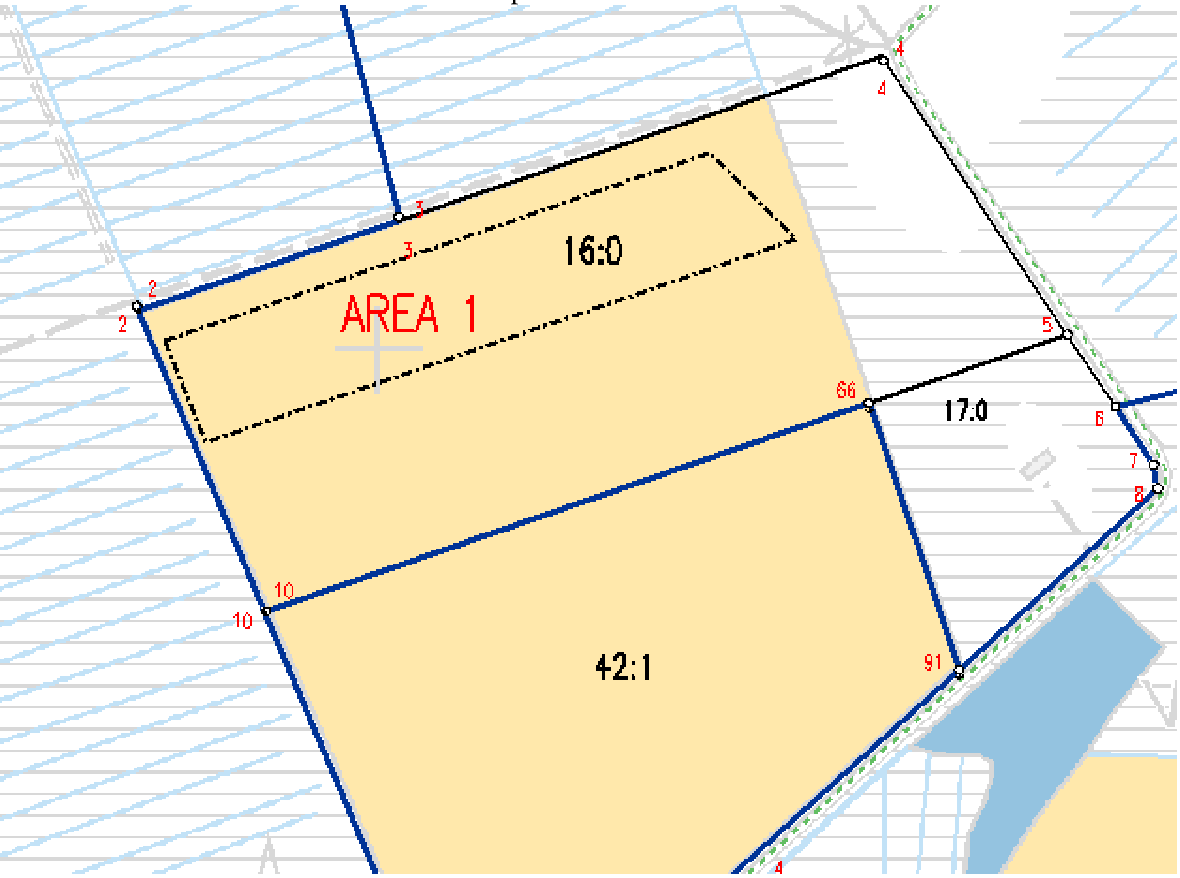
What if coordinates were held as the primary clause instead of the markers found on the field? In this scenario, the information contained on the cadastral map and database has to be accurate and all borders should be fixed. Vesa-Matti Mikkonen researched this possibility in his thesis in 2013 and determined that surveying all the inaccurate border marks to provide an accurate representation would take around 19,700 working days in the area of North-Ostrobothnia District Survey Office alone. This amount of labour is not possible to apply directly to other parts of Finland, because due to a historical lack of homogeny in the construction of cadastre. The Base Land Consolidation took place firstly in the western part of the country and the resulting cadastre is older than that found in eastern or northern parts of Finland. For that reason, more border marks have vanished here than in other parts of the country. However, the number gives a good indication of the amount of working days and expense where the system to be applied on the scale of the nationwide Finnish cadastral system.

Using natural shapes such as ditches, shorelines, roads, fences etc., could be a useful way to conduct cadastral proceedings without the need for field work. Many of the shapes are visible and possible to locate from ortho photos, but in covered areas such as forests, the ortho photo is not accurate enough to locate these shapes. One solution to this problem could be the images produced from laser scanned terrain data. In these images, even the smaller shapes of terrain become significantly more visible.

In order to test the accuracy and efficiency of the natural borders, I made four test ranges. For each range I measured the points/borders using ortho photos, laser scanned images and field surveys.

1.3.1 Test Area 1

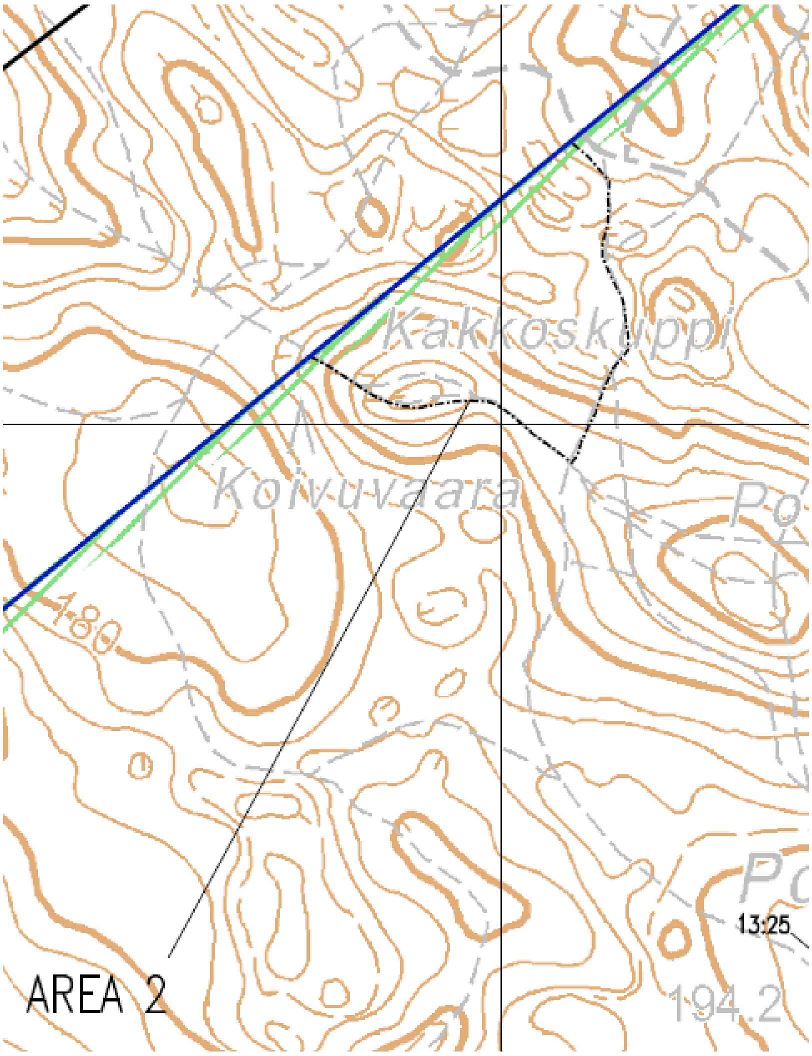
Test Area 1 is located in the village of Veneheitto in Vaala. The environment is open field and there are no obstacles. The goal was to measure a certain area bounded by ditches. The location of the test area is shown on Map 1.



Map 1. Test Area 1

1.3.2 Test Area 2

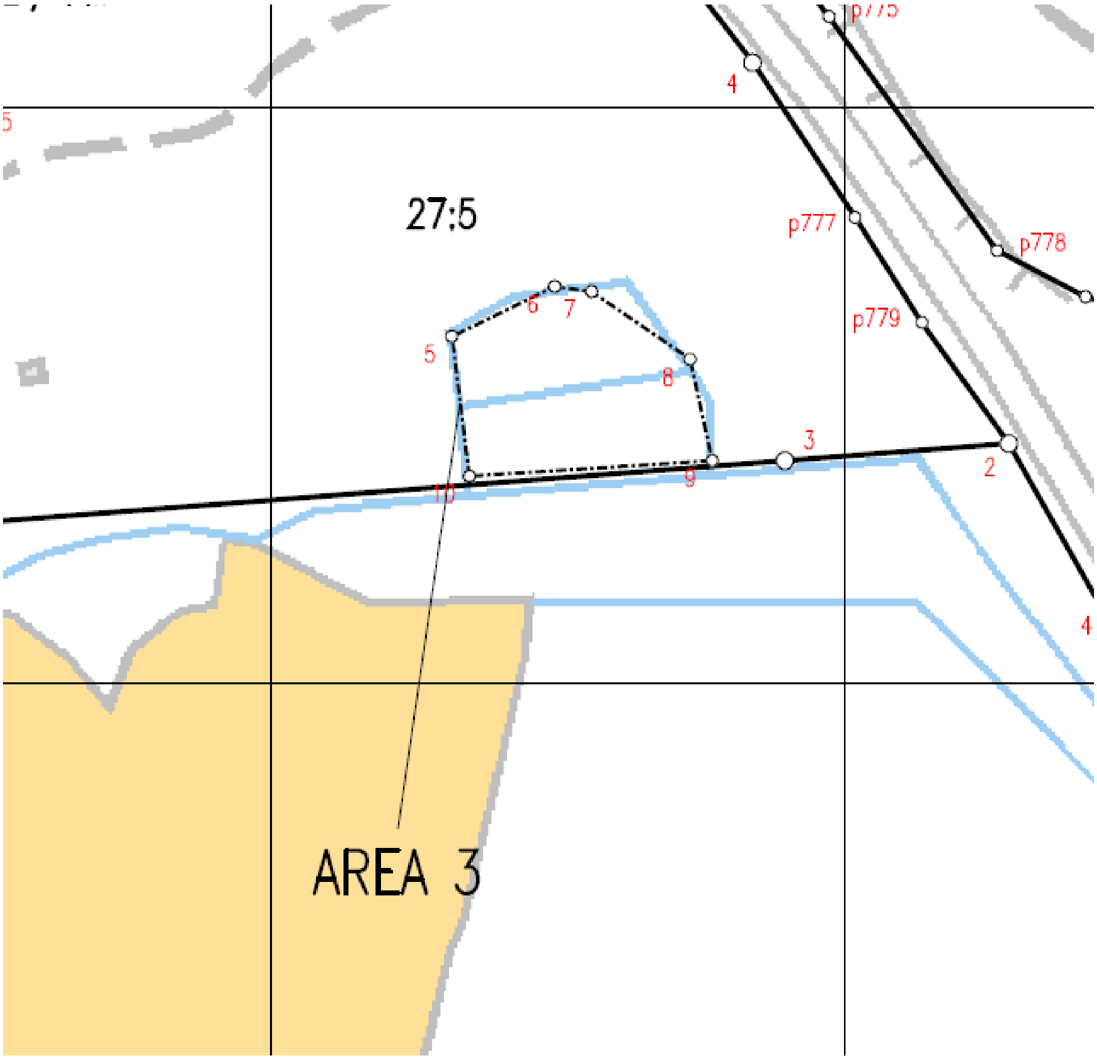
Test Area 2 is located in Rokua National Park and is bounded by roadways. The terrain is covered by pine trees, but the roadways are possible to locate from ortho photos and laser scanned images. Map 2 shows the location and terrain of the test area.



Map 2. Test area 2

1.3.3 Test Area 3

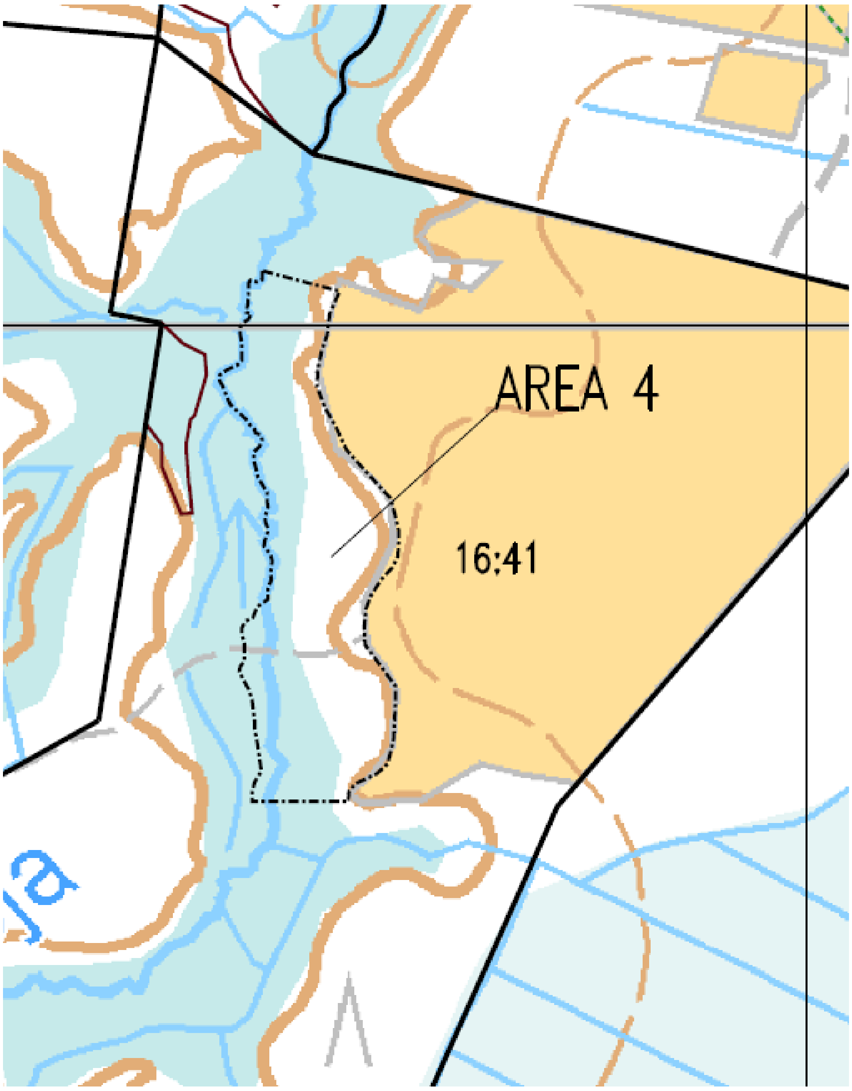
Test Area 3 is located in Utajärvi near the river Oulu. It is bounded from every side by ditches and the terrain is covered by tall pine trees. The goal of this test area was to measure the ditches marked on the terrain map. Map 3 shows the location and terrain of the test area.



Map 3. Test Area 3

1.3.4 Test Area 4

Test Area 4 is located in Vaala near the river Oulu. It is bounded on the eastern side to the edges of field and forest and on the western side it is bounded to the Lohioja brook. The terrain is covered by trees and bushes. Map 4 shows the location and terrain of the test area.



Map 4. Test Area 4

1.4 Field Surveys

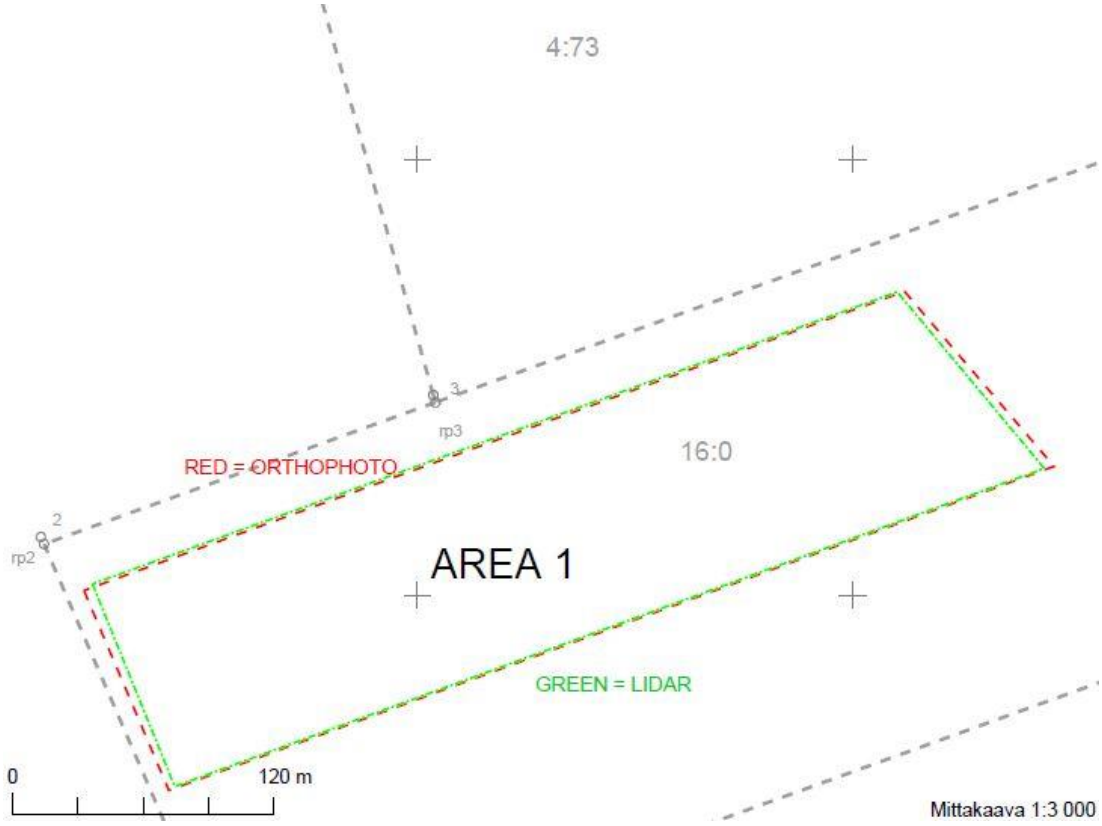
Field Surveys on Test Areas 2 and 4 were conducted on the 13th July 2013. All specified structures were surveyed using a Trimble R8 RTK-device. Test Area 2 was measured by using a Continuous Survey method to survey the midline of the roadways, and in Test Area 4 the middle point of the brook was mapped in normal mode. The Test Area 3 field surveys took place on August 15th and 16th 2013. Structures were surveyed using a Trimble R10 RTK-device.

The results of the field surveys were compared to earlier measured data in the office. On Test Area 1 there was no requirement to execute field surveys, as the results provided by ortho photos and Lidar images depends only the accuracy of the photo orientation.

2 ANALYZES OF RESULTS

2.1 Test Area 1

In this test area, field surveys were not conducted because the environment of the area was open field and the accuracy of ortho photo and Lidar images depends only on the orientation of images. As Map 5 shows, the results did not differ remarkably.



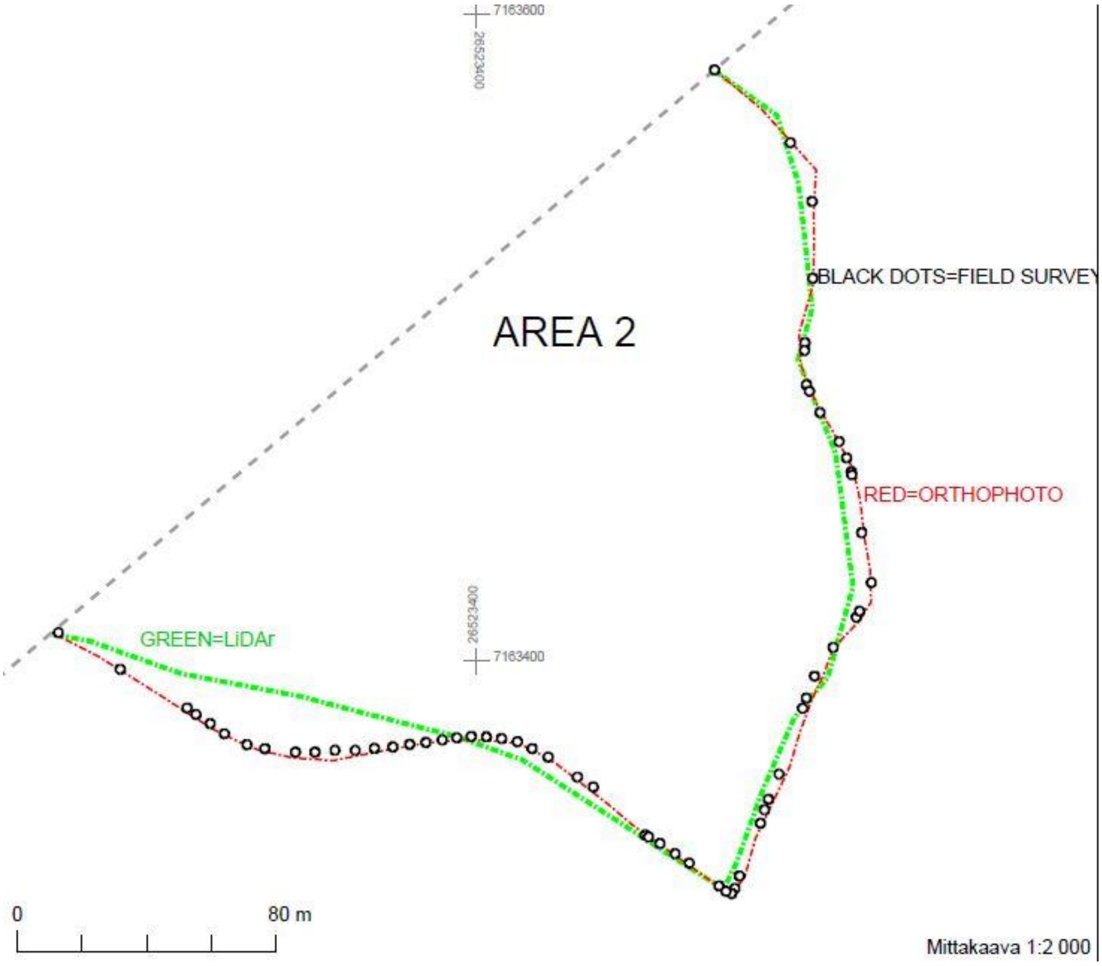
Map 5. Results of Test Area 1

2.2 Test Area 2

The results given by the mapping from ortho photos and field surveys did not differ remarkably. The roads from the Lidar image were possible to locate where the height differences were minor. However, when the roadway fell to the kettle hole, the accurate location was impossible to determine. Following shows the roadway falling to the kettle.

Surveying in Rokua national park

Field surveys took approximately 1 hour to conduct, and half an hour was needed to process the data. The ortho photos and Lidar images took approximately half an hour to process.

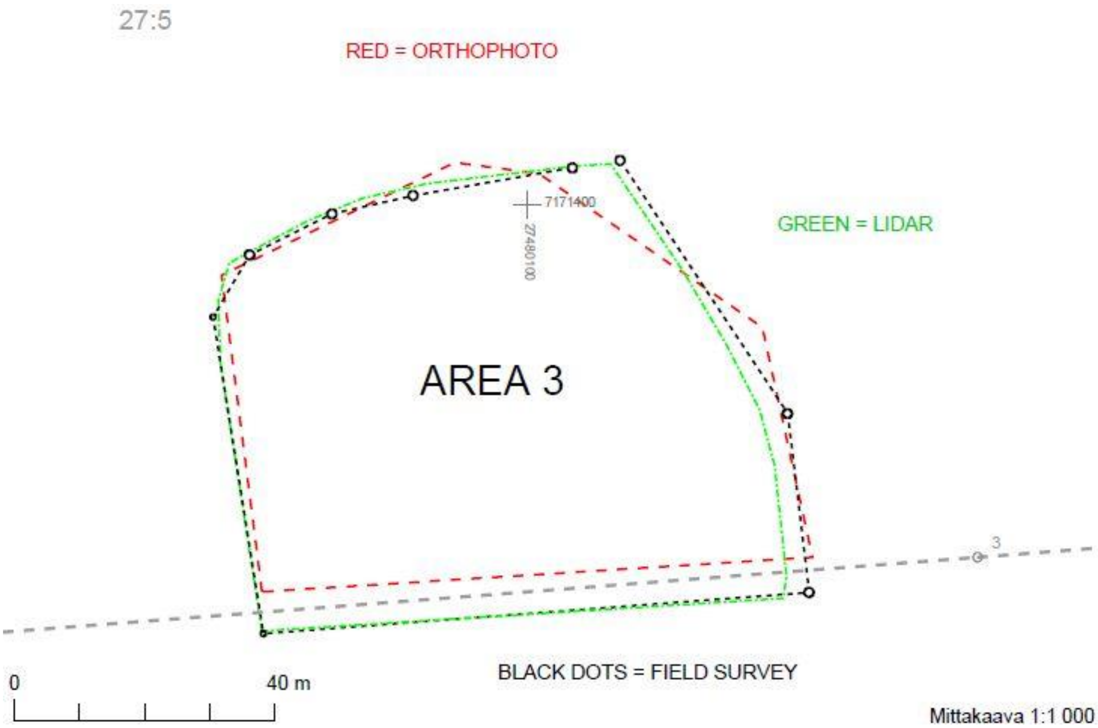


Map 6. Results of Test Area 2

2.3 Test Area 3

Differences between the results gained via the ortho photos and field surveys were significant. The ditch which was meant to form a new border was not visible from the ortho photos, and the location of some corners was approximately 5 metres different when measured from ortho photo and field surveys. Using Lidar images, the ditch was possible to accurately locate except in the eastern side of the test area. The maximum difference between field surveys and Lidar images was approximately 4 metres.

The field surveys took approximately 1.2 hours and a further half an hour was required to process the data. The ortho photos and Lidar images took approximately half an hour to process.



Map 7. Results of Test Area 3

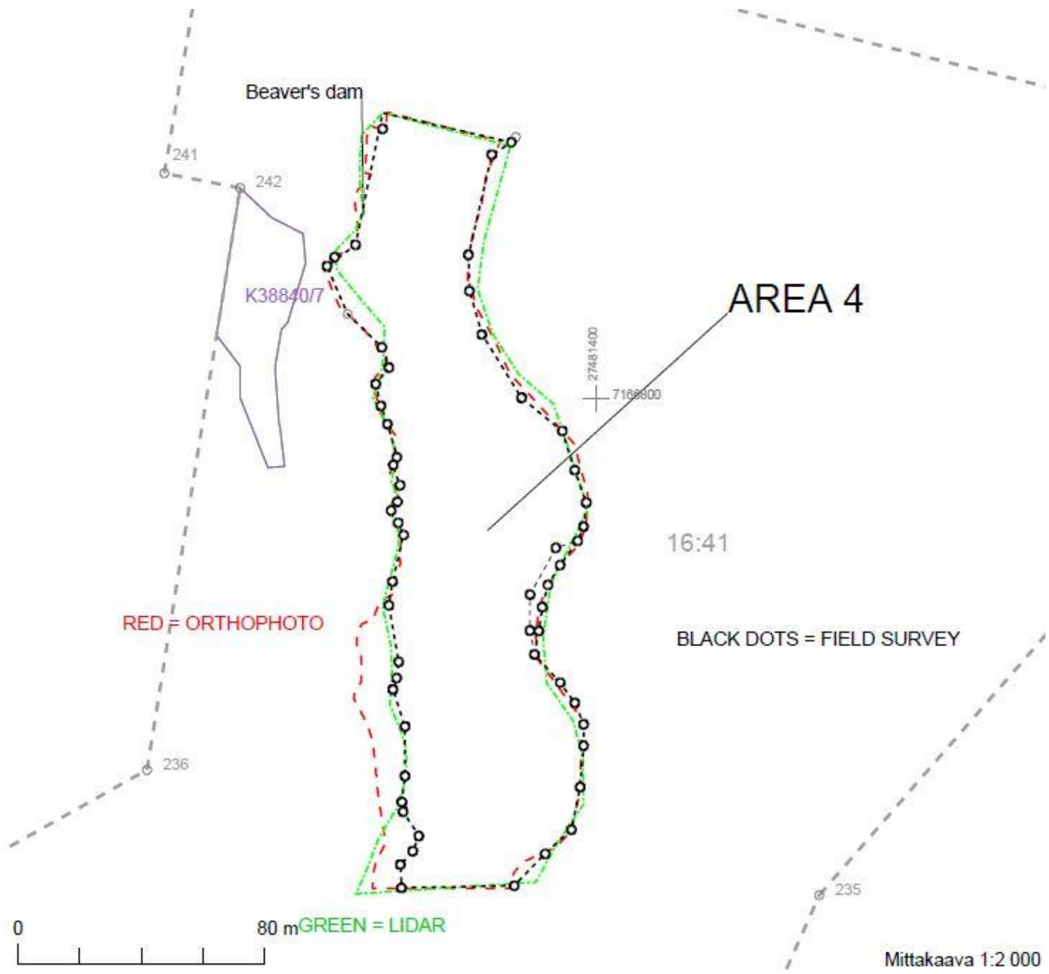
2.4 Test Area 4

The difference between field surveys and ortho photos (especially in the location of the brook) was considerable. Starting from the south and moving towards the north, the first 100 metres of brook mapped by ortho photos was mislocated approximately 9 to 12 metres from the real location. The cause of this error is the fact the brook was invisible (to the camera) in this area. When using Lidar pictures the brook was possible to locate quite accurately in most cases, but where the brook was covered by thick bushes, the picture was inaccurate. The brook was impossible to locate from pictures, because there was not enough measured data as not enough points were reflected back from the surface. Also, locating the edges of vegetation such as field was impossible because the vegetation was filtered out and there was only ground visible.

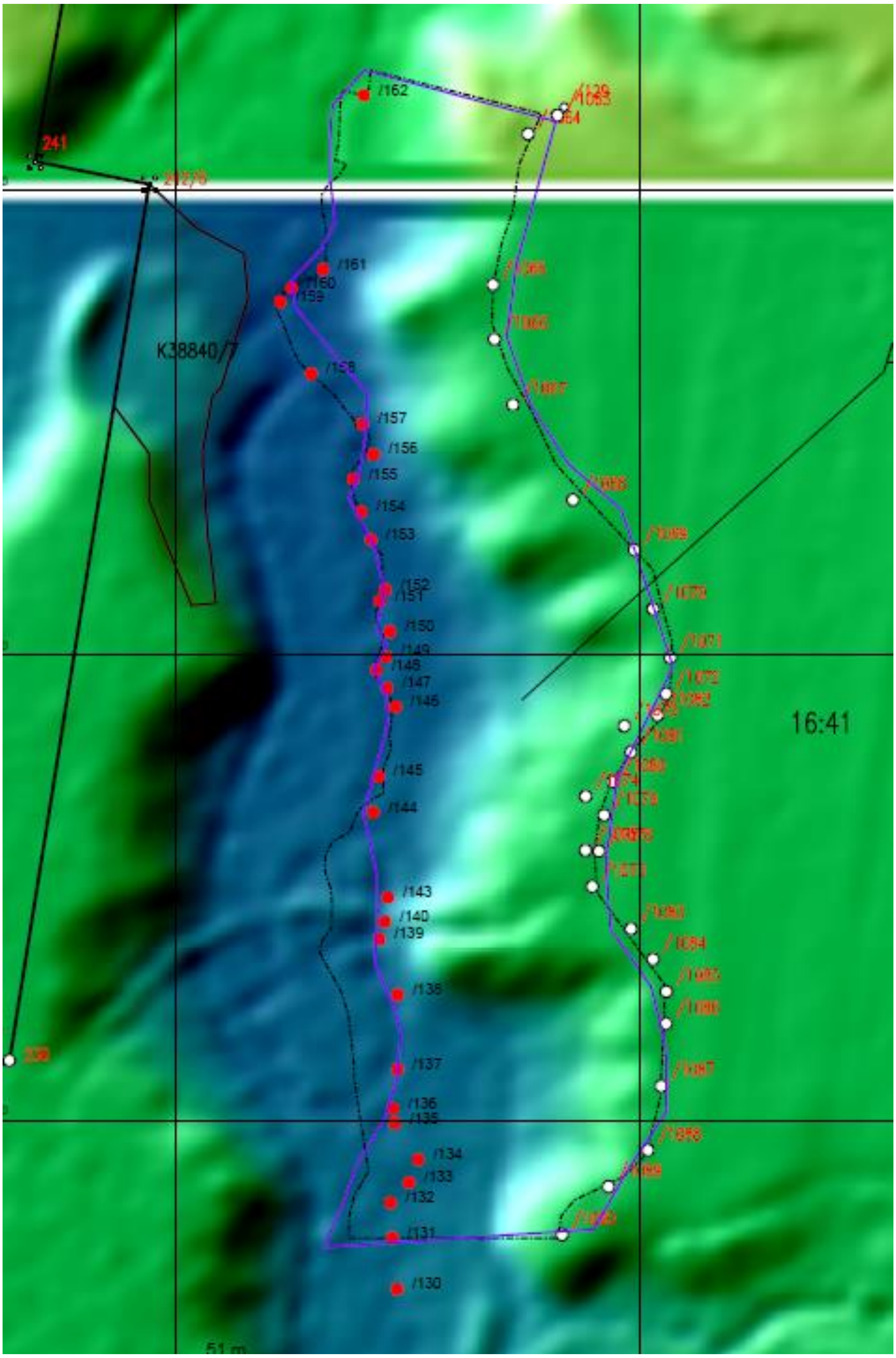

Where is the true location of field edge?


The Lohioja brook

The field surveys took approximately 1.2 hours and a further half an hour was required to process the data. The ortho photos and Lidar images took approximately half an hour to process from commencing to the demarcation of the new borders.



Map 8. Results of Test Area 4



Lidar image + measurements from Test Area 4

3 ACCURACY

Table gives the combined test results.

Test Area 1

	Aerial Ph	Lidar	Field survey	dAP-Lid[ha]	dAP-Lid[%]		dLid-FS[%]
Area [ha]	4,1408	4,0783	X	0,0625	1,51	X	X

Test Area 2

	Aerial Ph	Lidar	Field survey	dAP-FS[ha]	dLid-FS[ha]	dAP-FS[%]	dLid-FS[%]
Area [ha]	3,2771	3,1176	3,2760	-0,0011	0,1584	-0,03	4,84

Test Area 3

	Aerial Ph	Lidar	Field survey	dAP-FS[ha]	dLid-FS[ha]	dAP-FS[%]	dLid-FS[%]
Area [ha]	0,4486	0,498	0,5072	0,0586	0,0092	11,55	1,81

Test Area 4

	Aerial Ph	Lidar	Field survey	dAP-FS[ha]	dLid-FS[ha]	dAP-FS[%]	dLid-FS[%]
Area [ha]	1,3076	1,2725	1,1855	-0,1221	-0,0870	-10,30	-7,34

Comments
At field survey the Lohioja -brook was not able to survey completely. Approximately 40 meters was unable to be surveyed because of flooding caused by a beaver's dam.

From these results, it may be concluded that in open areas, ortho photos may be used to determine new borders with a high level of precision. In covered areas, the pictures produced from Lidar data can be used to identify the shapes of terrain. The differences in total areas are minor in good conditions and the differences are possible to reduce when using the combination of the Lidar images and the orthophotos.

4 CONCLUSIONS

Is field marking of the border necessary and is it possible to use only coordinates and visible shapes to determine such borders? In most cases this is possible. You can demarcate the new border by using a combination of ortho / satellite photos to determine the edges caused by vegetation and the visible shapes of terrain, and also use the images produced from Lidar data. When compared to reality, the errors are minor. After determination, the new border has coordinates and the border on the field is also visible.

Difficulties could appear when using non-current data and this raises the question of how to obtain/maintain fresh images of a certain area. One answer could be the use of satellite technology, as satellites can cover a huge area a short time. Technological development will produce more accurate cameras and Lidar sensors, therefore gaining the live images from satellites lies inside the limits of possibility.

You could also use an Unmanned Arial Vehicle (UAV) to produce a digital terrain model of a certain area with high degrees of accuracy even with today's current technology. This equipment will likely be more accurate and cheaper in the future and could provide one possible way to collect up-to-date data from the field. UAV's could possibly become fully automatic 'surveyors' which fly and model the ground constantly.

The technology to determine the borders to natural shapes accurate enough exists already. The only gap to adapt this method to production is the will and the demands of accuracy. The Finnish cadastral system is no need to be homogeny, the less value land ought to be surveyed less accurate. The method needs changes to the legislation and to the land surveyor's attitude too but it is possible. This would be necessary when reducing costs of cadastral proceedings.

REFERENCES

Sami Mantere master thesis 2014

BIOGRAPHICAL NOTES

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