Use of Laser Data as a Tool when Calculating the Volume of Standing Forest in Property Tax Assessment of Agricultural Properties

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Key words: Property Tax Assessment, Forest, Laser Data, GIS

SUMMARY

Sweden has a long tradition of forest property valuation but also of tax assessment of properties, including assessment of forest land. However, one big issue in assessment of forest land is the volume of standing forest (stem volume) which is an important value factor, i.e. to estimate cubic meter (m^3) solid volume per hectare. An exciting technological development is ongoing to improve the methods for calculating the standing volume as well as other data on the forest. One of these methods is the use of laser data.

The purpose of this paper is to present how Lantmäteriet (the Swedish mapping, cadastral and land registration authority) applies the laser data as a tool and aid in the preparatory work, which constitutes an important part of the assessment of the forest land which is a part of an agricultural property.

Lantmäteriet has developed a new national elevation model based on airborne laser scanning. The model provides very accurate ground height values and as a side effect height data measurements of the forest. The Swedish Forest Agency and the Swedish University of Agricultural Sciences (SLU) have used the laser data in combination with existing sample plots based on National Forestry Inventory carried out by the SLU to improve the information on forest data, such as stem volume (standing volume). The accuracy obtained for estimates of the standing volume is similar, or better, than those obtained with traditional subjective field surveys.

For the particular application in the preparatory work a GIS application has been developed. This paper presents a number of examples of how the GIS application can be used as an aid for both the preparatory work as for the tax assessment.

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1. INTRODUCTION

Sweden has a long tradition of forest property valuation. One reason for this is the importance of the forest land and the forest industry for the Swedish economy. Of Sweden´s total area about 55 per cent comprises productive forestland (22.5 million hectares). In addition, about 328,000 non-industrial private (individual) owners own 50 per cent of the forest land area, which is divided into 238,000 management units with a size often in the order of 2 to 200 ha.

Sweden has a long tradition of tax assessment of properties (Bäckström & Jonsson, 2015). The valuation standard used in Sweden is the market value at highest and best use. Assessed values are equivalent to 75 per cent of the market value two years before the year of assessment (taxation).

The present system implies, in short, that all properties are subject to a general property tax assessment every sixth year followed by a simplified tax assessment three years later. The Swedish Tax Agency is the authority that is responsible for assessment and taxation of properties. As a complement to the legislation, it also issue detailed instructions on how the work should be carried out. There are also detailed instructions for examination of sales which are forming an important part of the preparatory assessment work. Lantmäteriet (the Swedish mapping, cadastral and land registration authority) provides important assistance to the Swedish Tax Agency by being responsible for most of the technical and methodological part of the preparatory assessment work, a work which is highly dependent on the good quality of the input data relating to the sales. This is due to that the market comparison method is the main method used for determining assessment levels in different parts of Sweden. A major part of the preparatory work thus comprises analyses of sales that have been adjusted to the reference year and also comprises the sales for the last two years before the reference year for the specific assessment.

The assessment of the forest land is based on two different models. A more simplified model is used for the valuation of units less than 30 hectares, and for the first 29 hectares of larger forest holdings. A more comprehensive valuation model is used for units larger than 29 hectares.

The simplified model (units < 30 hectares) takes the following value factors into consideration:

- Land area - forest area in hectares
- Standing volume - the volume of growing forest in cubic meters per hectare (m^3/ha) of all species, both broad-leaves and conifers.

The comprehensive model (units >= 30 hectares) takes into consideration the value factors:

- Land area
- Site quality - the timber-producing ability
- Standing volume of conifers - the forest growing stock in cubic meters per hectare (m^3/ha) of conifers
- Standing volume of broad-leaves - the forest growing stock in cubic meters per hectare (m^3/ha) of broad-leaves.

2. BACKGROUND

Value factors such as forest land area and site quality are constant and they do not change over time. The land area might change if the property has been subject of subdivision or reallotment but that kind of changes are easy to monitor and the quality in the register is good regarding these value factors. The big issue in assessment of forest land is the standing volume, i.e. to estimate m^3 solid volume per hectare. One can generally never determine the volume exactly, it is only an estimate. Furthermore, the volume is always changing over time, which is due to both the continuously growing and by the presence of harvesting and sometimes also storm damage. When value factors should be determined before an assessment (taxation) of a forest property, the estimate of the property´s growing volume is often a difficult issue, particularly for those forest property owners who do not have a recently made standwise forest management plan or a similar skilled estimation of the growing forest. This means a high risk of incorrect values in the tax assessment register regarding standing volume for individual properties, which are highly detrimental both to the preparatory assessment work as to the actual property taxation.

A main issue with physical forest inventories, so also when preparing forest management plans, is the high cost. Physical inventories need people on the ground who may not cover more than a limited area per day. Thus the forest management plans are relatively expensive, and especially the owners of smaller forest properties often do not acquire such forest plans. Another disadvantage is that the management plan loses its relevance for some time, not least with regard to the growing volume, unless the plan is updated to reflect the growth and eventual later implemented harvesting.

Except for the problems mentioned above, the Swedish Tax Agency wants to find methods using modern technology that allows them to gather information without asking the individual forest owner about the data needed for the assessment. If the authority has access to such information from other sources the information can be pre-printed on the tax forms which are sent out to forest property owners in connection with the preparatory work as well as with the actual assessment in a similar manner as is done e.g. at ordinary income declarations.

In connection with the preparations for the general assessment of agricultural properties in year 2017 has a new technical aid (GIS), based on laser data, been used as a tool to facilitate the estimations of the standing volume of individual properties.

Furthermore, a new land use class was created before the general assessment in 2017, “Productive forest land with felling restrictions” (In Swedish *“Produktiv skogsmark med avverknings-restriktioner”*). This land use class contains formally established nature reserves and habitat protection areas (*naturreservat* and *biotopskydd*). The area divided between nature reserves and habitat protection areas can be visualized in the form of polygons in the associated GIS.

3. LASER DATA

Lantmäteriet´s new national elevation model based on airborne laser scanning (fig. 1) provides very accurate ground height values and as a side effect height data measurements of the forest. The Swedish Forest Agency and the Swedish University of Agricultural Sciences (SLU) have used the laser data in combination with existing sample plots based on National Forestry Inventory carried out by the SLU to improve the information on forest data, such as stem volume (standing volume).

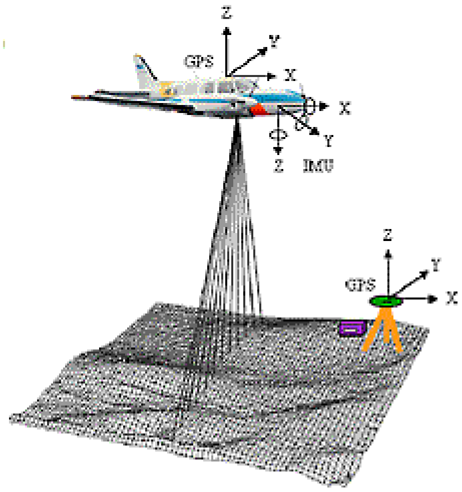

Fig. 1. Laser scanning from an airplane

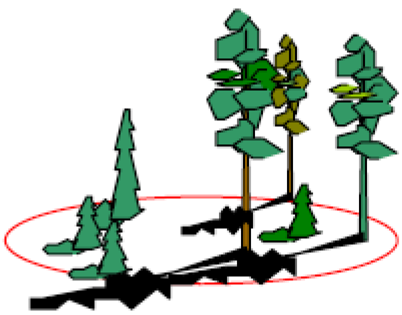

Fig. 2. Field plots from the National Forest Inventory (NFI)

The forest products are produced by a combination of laser scanned data and sample plot data from the National Forestry Inventory (NFI) (fig. 2). The production of a nationwide forest data base in Sweden started in 2013 and continued until 2016. The project is financed by the Swedish government and managed by the Swedish Forest Agency.

The laser-scanned area is divided into a grid (raster) of square cells, or pixels, 12.5 x 12.5 meters using linear regression and the area based method. Laser and field data from test areas, surveyed by the National Forest Inventory, are then connected together so that from laser data it is possible to estimate forest variables grid cells across the scanned area.

Variables that are calculated are:

– Stem volume (m^3/ha)
– Above ground tree biomass (tonnes/ha)
– Basal area (m^2/ha)

- Mean tree height, basal area weighted (dm)
- Mean stem diameter, basal area weighted (cm).

The results can then be aggregated to the population level by calculating the average of all grid cells that are part of a portfolio.

In the production regression is used to obtain unbiased estimates, meaning that the value of the estimated variables on average to be correct. Since the regression method is model-based and allows interpolation it works well even if you have relatively little field data. However, there is a risk that areas with high growing volume is underrated and areas with low growing volume is overestimated, which must be considered when using the material. Deciduous forests can also get a bad estimate, and if the scan is made during the summer, there is a risk of forest data for areas with broad-leaves to be overestimated.

The National Forest Inventory has a large number of sample plots which combined with regression give good results over Sweden on average. When developing the regression functions only plots of productive forest land are used, but the allocation of forest data to the grid cells are made for all land. Outside of productive forest **land**, or unusual tree species composition, estimates should be used with caution. Regardless of forest type, however, the estimation of tree height is consistently very good. The predictions of stem volume had a root mean square error (RMSE) in the range of 17,2-22,0% (Nilsson et al., 2016) and it was concluded that the prediction had an accuracy that were at least as data good as achieved at regular field estimations.

4. USE OF LASER DATA IN THE PREPARATORY ASSESSMENT WORK

In connection with the previous property taxation of agricultural properties, FFT2014, kNN-estimation via satellite images together with raster data covering the whole Sweden was used, described by Bäckström & Jonsson (2015). However, when the Swedish Forest Agency and SLU in 2015 took out forest basic data, based on Land Survey laser data for the new national elevation model and the National Forest Inventory plots for the whole of Sweden, and simultaneously published an open map service on the Internet, this was judged to be an even better aid and support for the property taxation.

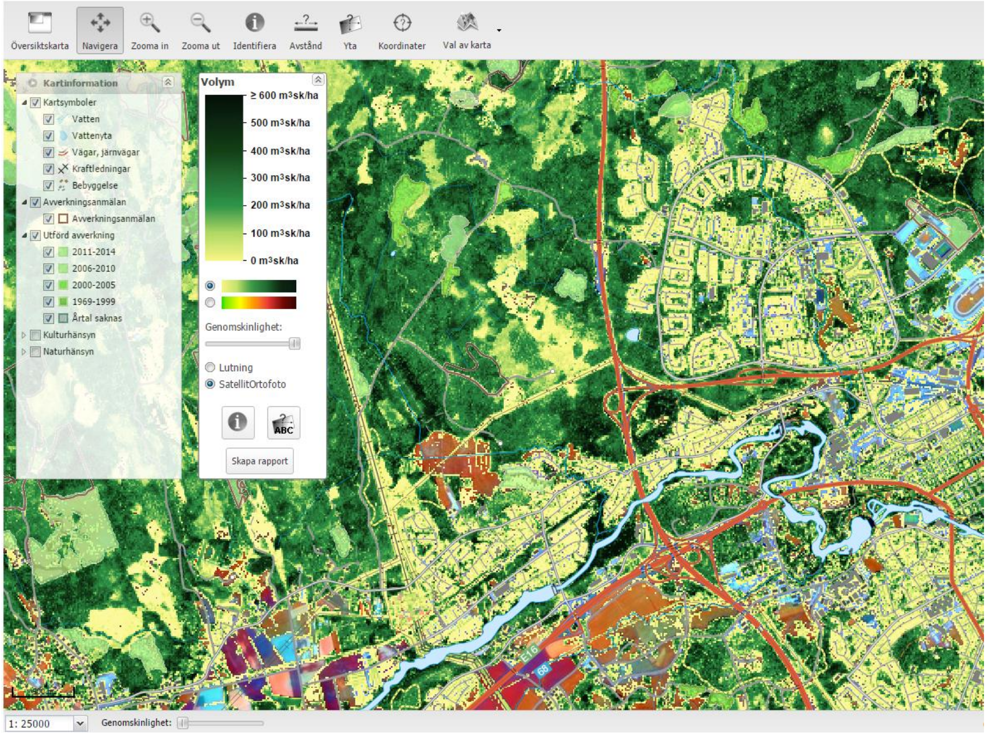

Fig. 3. Free available forestry maps from laser data on Internet at the Swedish Forest Agency, http://www.skogsstyrelsen.se/skogligagrunddata

Lantmäteriet has used the layer that contains the volume estimates from the basic data. Further processing has been made to distinguish different types of land use. This has been done with the help of land cover data (Naturvårdsverket, 2014) in order to determine what is forest land and what is arable land, grazing land, etc. The same information can also be given only for a specific forest property. Problems have arisen since the definition of land use classes differ in land cover classification and the type of land use in the property taxation. It has been especially difficult to determine the boundary between forested bog (swampy area) and poor quality woodland. Other layers of protected woodlands have also been used to separate the protected forest land from production forests (fig. 3).

5. EXAMPLES OF HOW THE TOOL WORKS

5.1 The GIS application

For the particular application in the preparatory work we have developed a GIS application in Web App Builder for ArcGIS (Portal for ArcGIS), ESRI. The application and examples how the tool can be used are illustrated in the following fig. 4 to fig. 18.

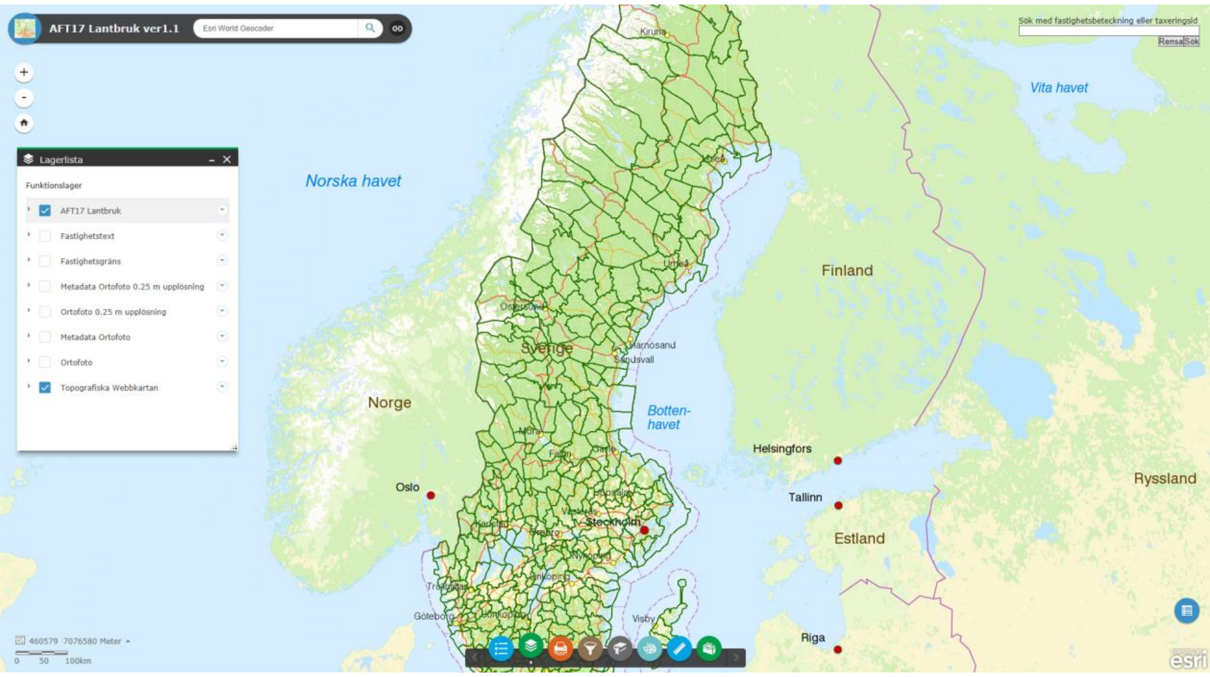

Fig. 4. GIS application in Web App Builder for ArcGIS

When developing the application, we have used the following data:

- Layer of standing volume from the nationwide forest raster database based on laser scanning, Forestry maps", *Skogsstyrelsen* (Swedish Forest Agency)
- Layer of year of scanning (Forestry maps), to be able to manually calculate growth in volume.
- Layer of land data cover, CORINE
- Layer of water (including rivers, lakes, sea)
- Layer of recently made final fellings, *Skogsstyrelsen* (Swedish Forest Agency)
- Layer of protected forest land

The tool for standing volume calculation is in most cases used for the properties where we do not receive data from the property owner, but also for properties that clearly differ in terms of value in relation to volume and in cases where the property is subject to other forms of protection measures which can lead to manual correction of the value.

The tool has also been used to pre-print protected area on the declaration form. When the laser scanning to produce new elevation model lasted several years (2009-2015), this means that even forest data refer to various years, see fig. 5. If the laser data have become too old it may be necessary with the enumeration of the increment. It can be done with simple increment percentages manually depending on the number of increment seasons elapsed.

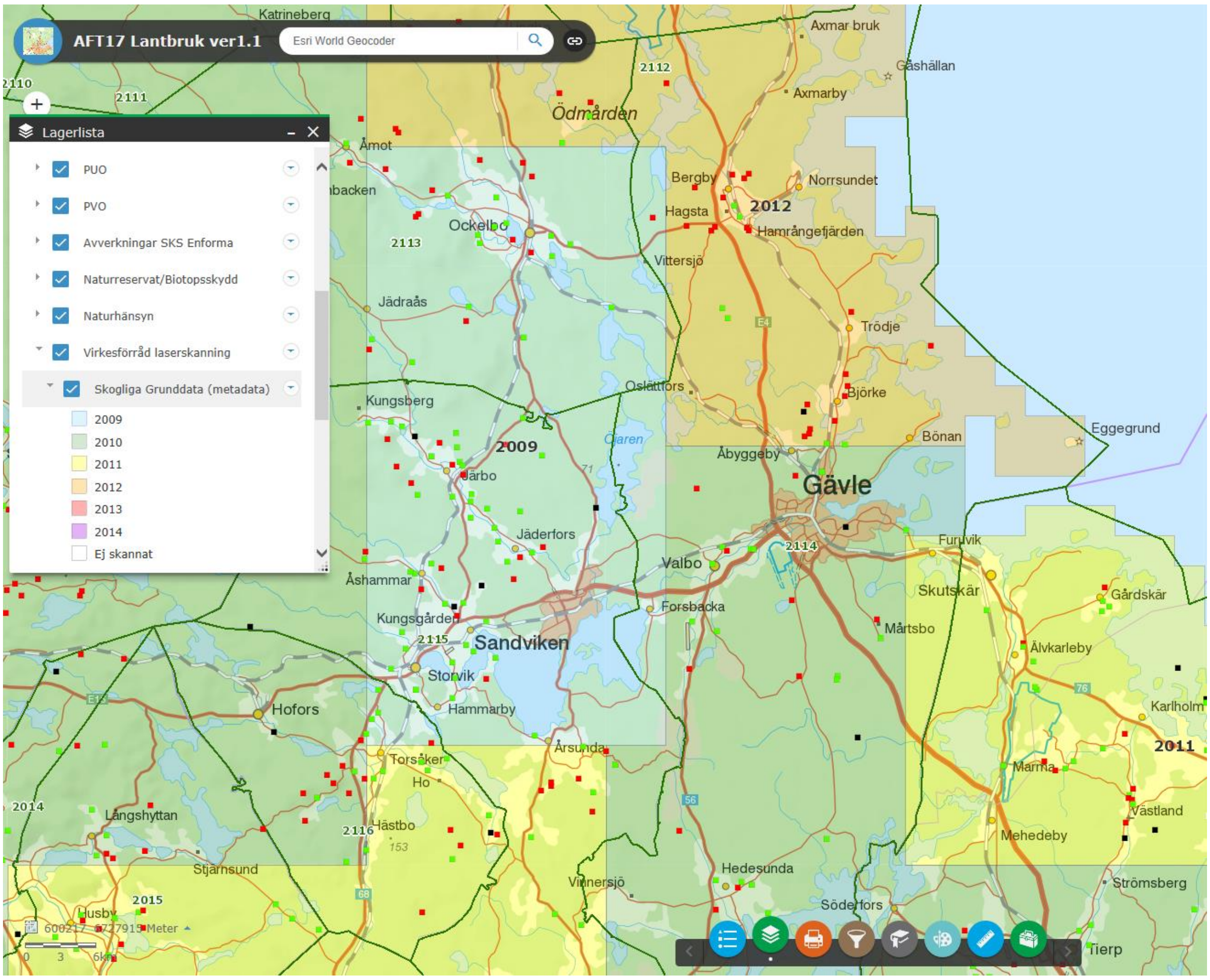

Fig. 5. Example of different years of inventory (year of scanning)

We have also considered final (regeneration) felling areas that have been carried out after the laser scanning was performed. Information on areas which have been recently final felled have been received from the Swedish Forest Agency which brings out these data with the help of satellite image analysis using the tool ENFORMA in ArcGIS combined with notifications of final felling. Final fellings that arose after the scan have been assigned zero volume.

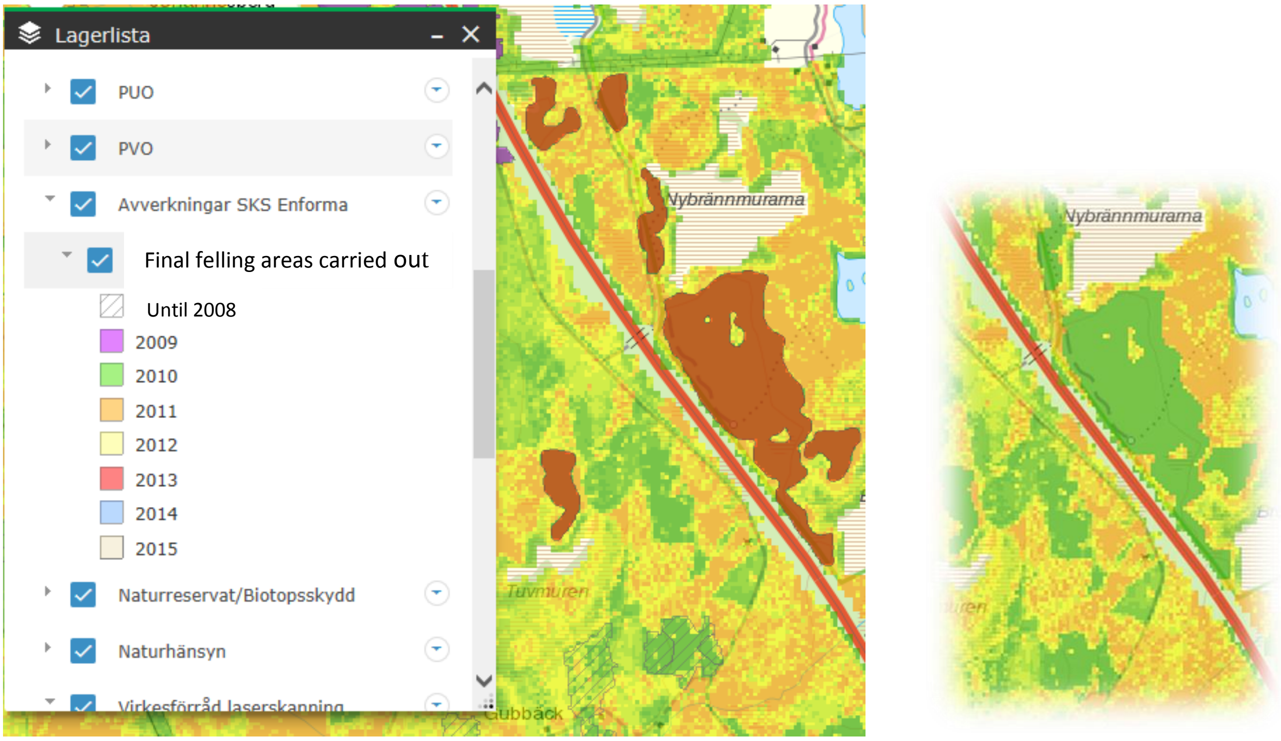

Fig. 6. Layer of recent final felling. If final felling is performed after laser scanning the volume is reduced to zero in the layer volume.

In the property tax assessment we must be able to separate the ground in the land use classes appearing in the assessment. There may be forest on swampy areas, arable and grassland as well as on land (for housing), which is not to be included in the area of summation of the forest land. To do that, we use a layer of ground cover data

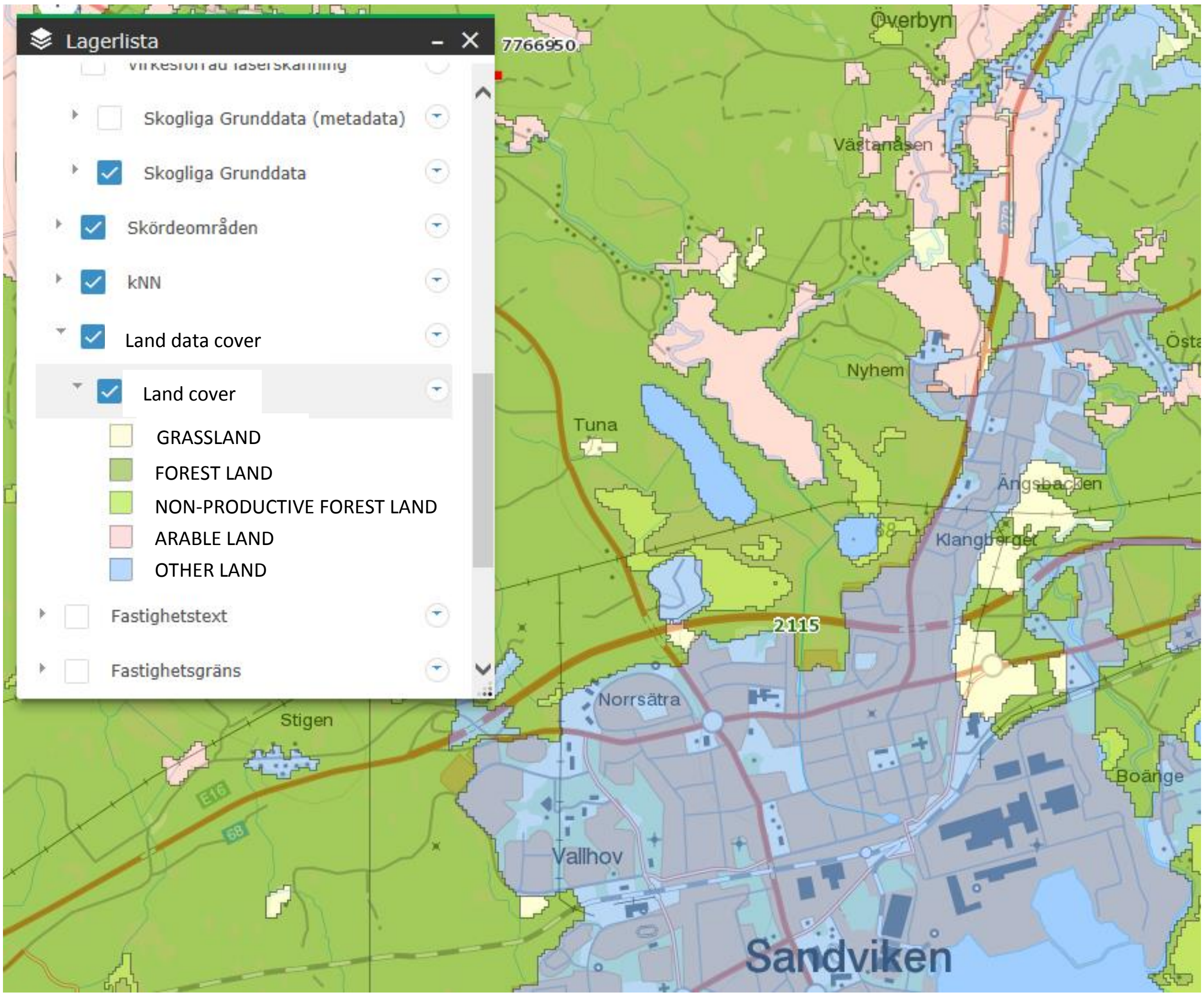

Fig. 7. Example of layer of land data cover. Forest in dark green and non-productive land with forested bog (swampy area) in light green color.

We also separate forest land allocated to habitat protection areas and nature reserves. There, the proprietary rights may remain with the property owner, but the right to use the forest has been restricted. In the tax assessment is assigned different values of forest land with and without logging restrictions. Therefore, it is important to distinguish between the areas.

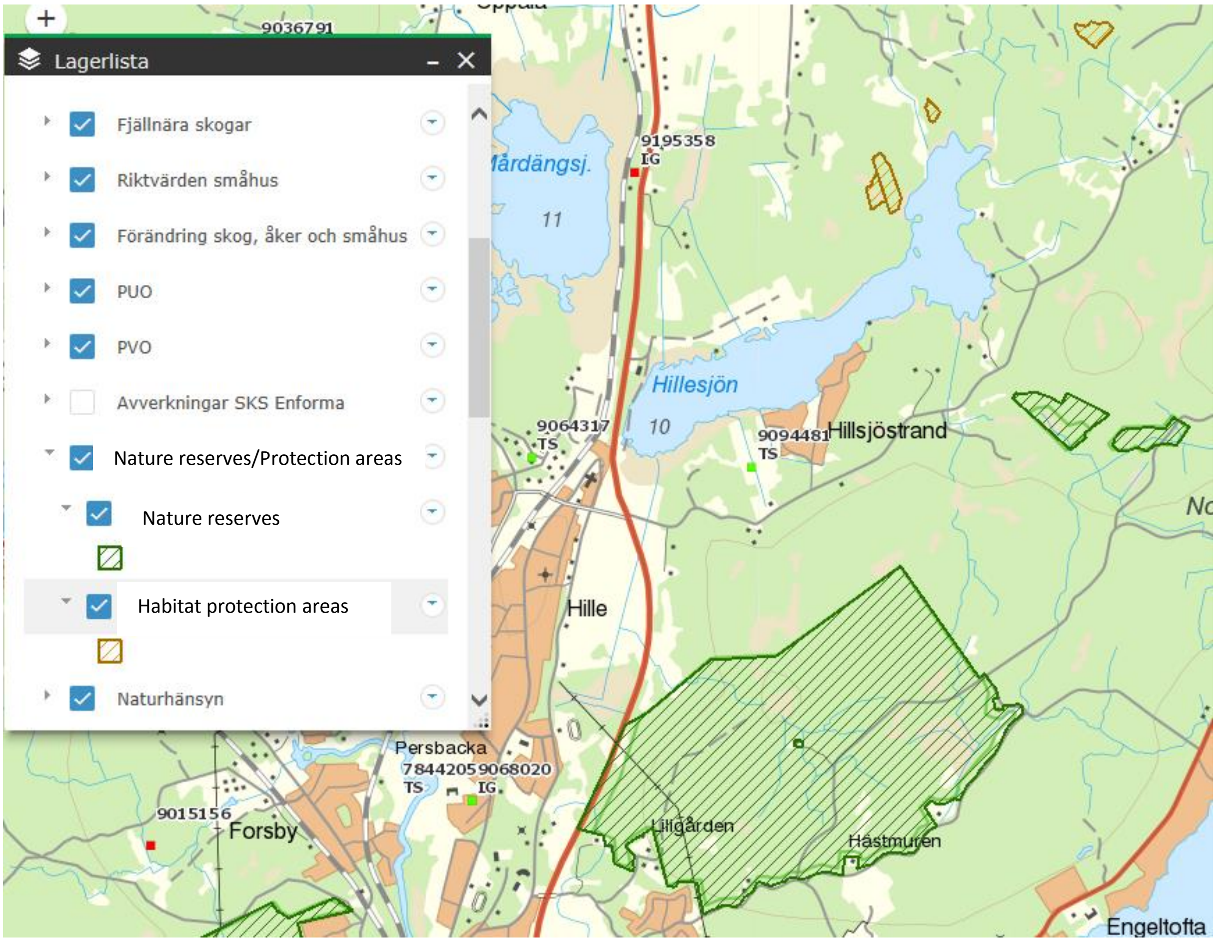

Fig. 8. Example of layer of protected forest land. Protection form *"Naturreservat"* (nature reserves - larger areas) and *"Biotopskydd"* (habitat protection areas - often small areas).

5.2 Different ways to search for properties

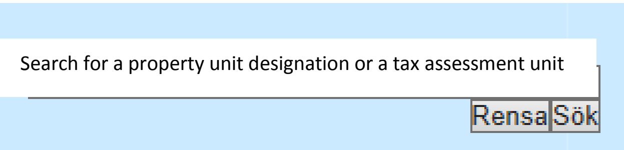

Fig. 9. It is possible to search for an individual property or tax assessment unit (consisting of one or more properties)

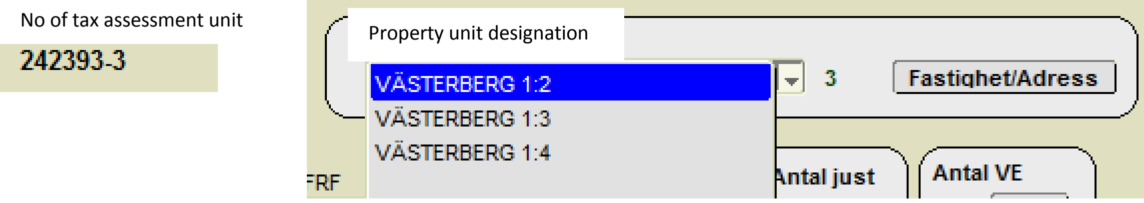

Fig. 10. Example of numbering of a tax assessment unit (including three properties)

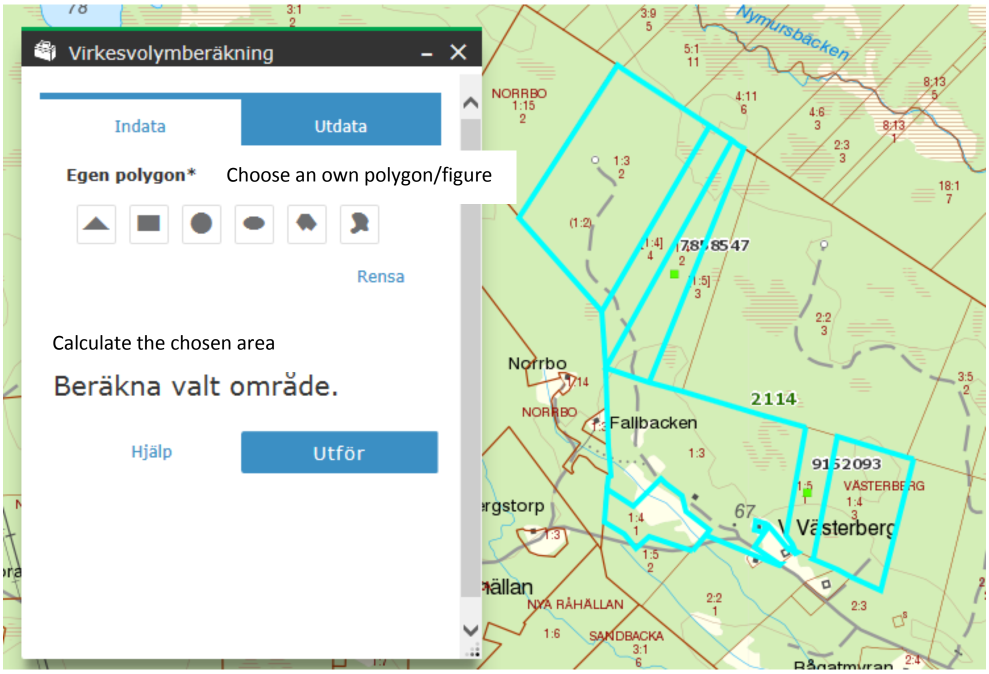

Fig. 11. The tax assessment unit on the map

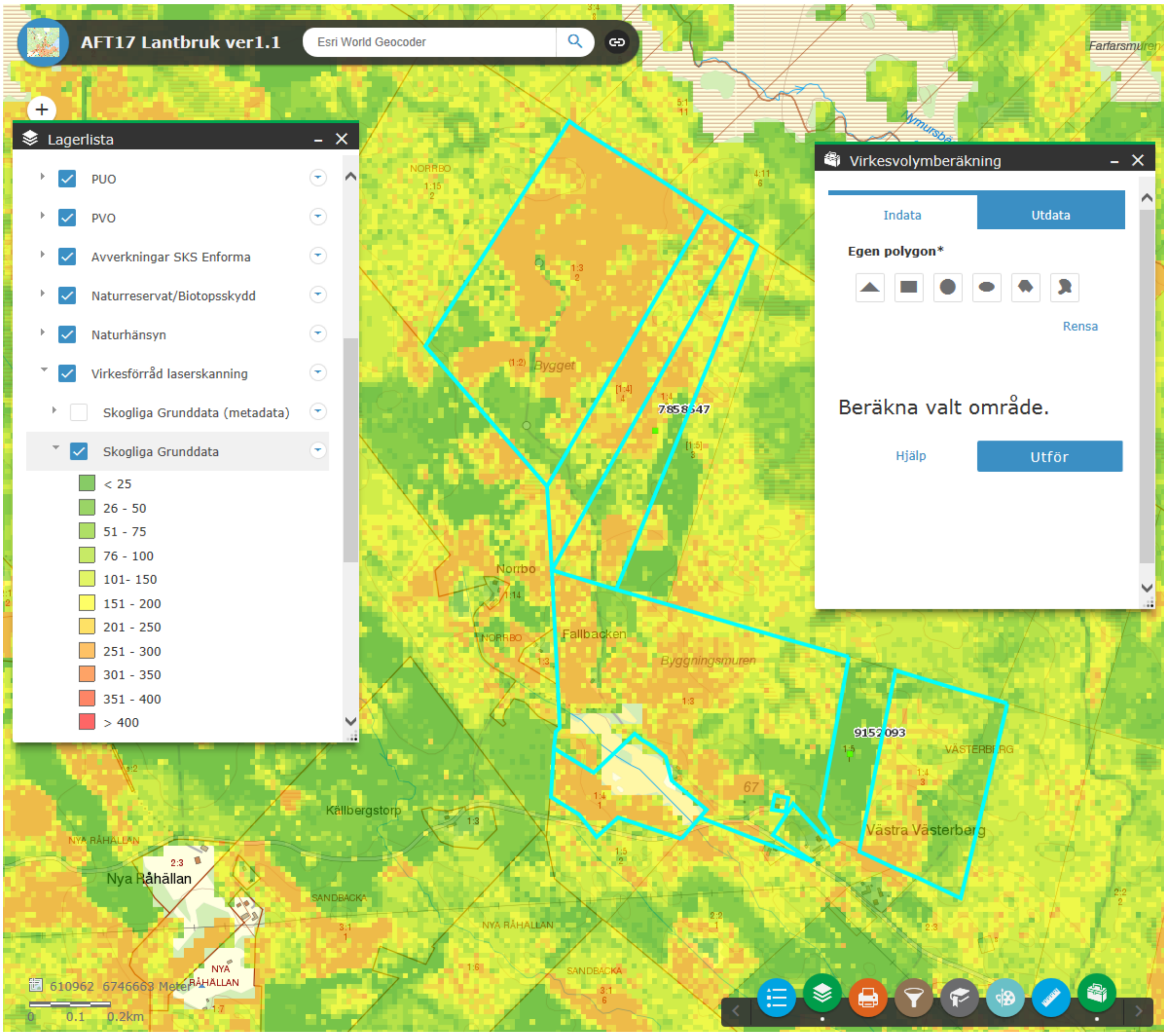

Fig. 12. The forest map layer is active and the boundary of the assessed unit is still marked on the map. The green color symbolizes very low standing volume and the red color very high standing volume.

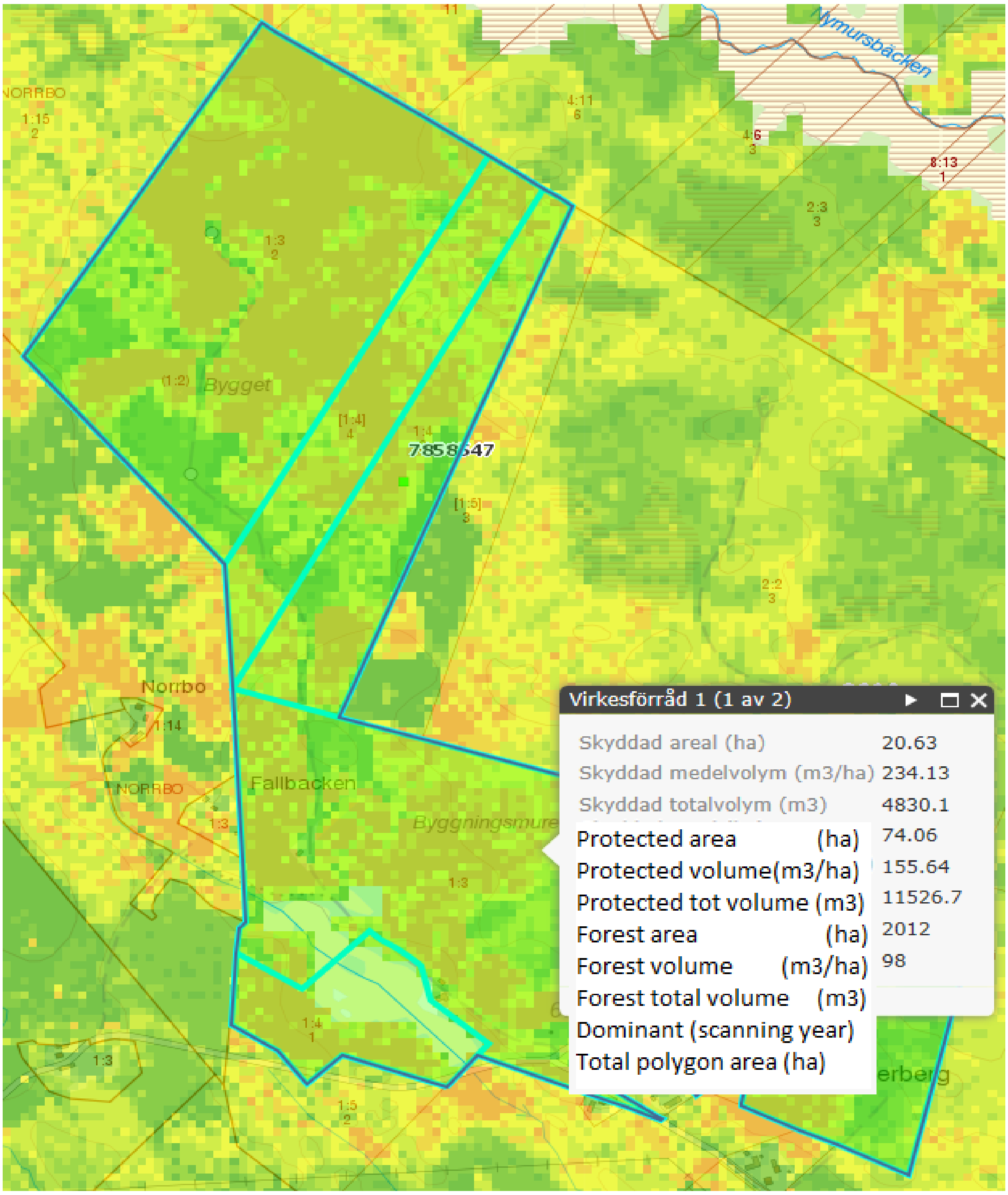

Fig. 13. Example of the result of a calculation of the standing volume. Here you can find the area and volume of protected forest and of unprotected forest and the year that is dominant in the laser scanning data (if the data originates from different years).

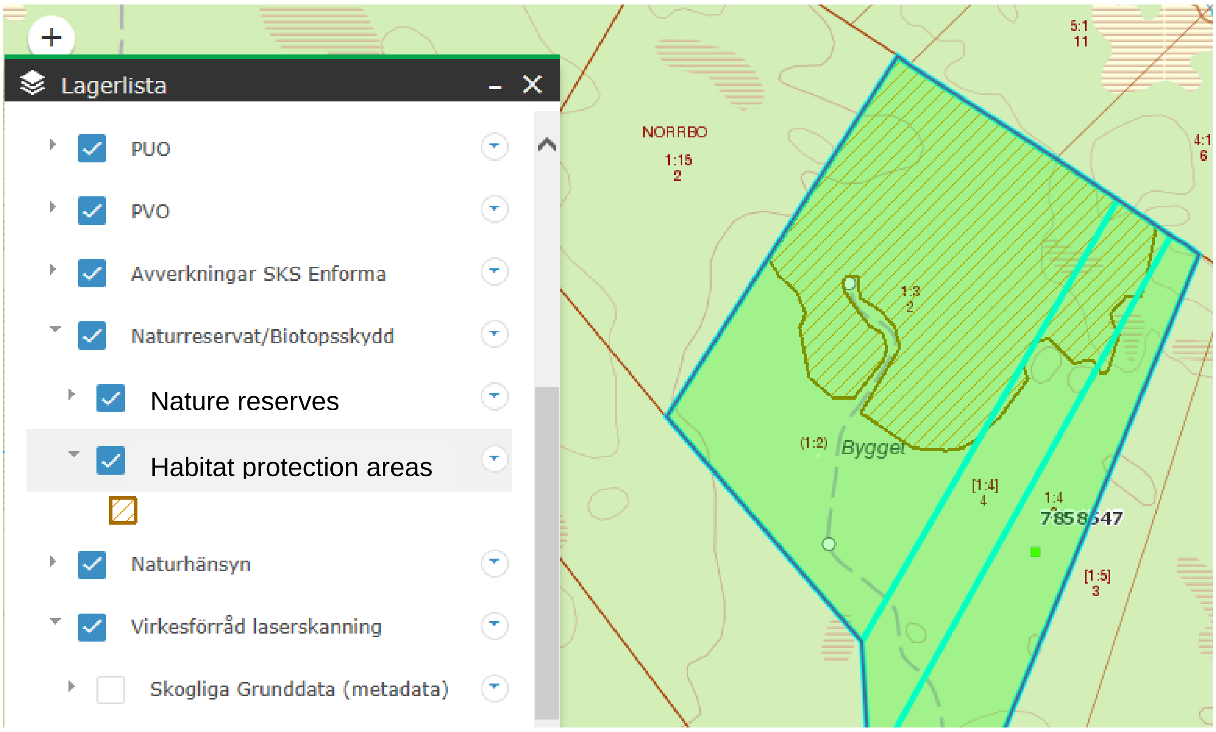

Fig. 14. A conservation area *(Biotopskydd)* of 20.63 hectares is marked with lines

Sometimes you do not want to calculate the entire estates or assessment units but only the parts of a property, for example in areas allocated for culture or environment or to count out the volume of felled areas as property owners have reported in the declaration. We have therefore introduced the possibility to draw their own areas through different figures. The multipolygon is the figure who gives the best opportunity to designate the desired area.

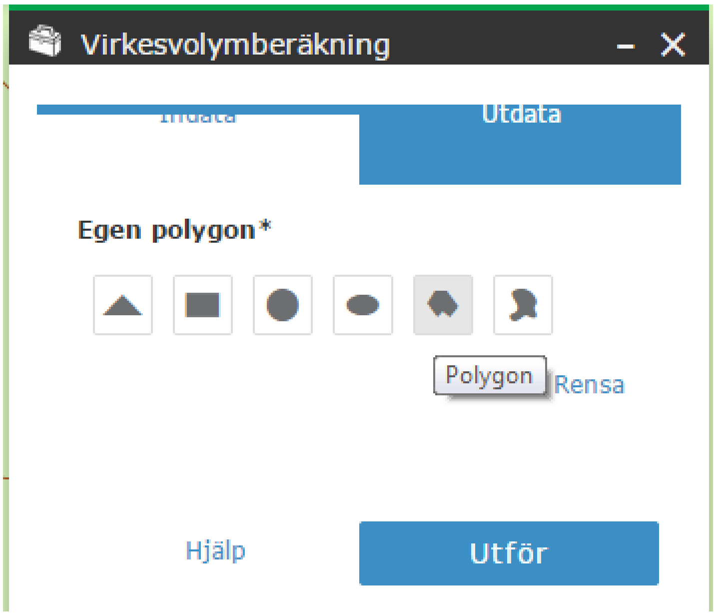

Fig. 15. Example of calculation of standing volume. Choose figure under "*Egen-polygon* - Custom Polygon" to "draw" the desired area to perform timber volume calculation on. The best option is Polygon.

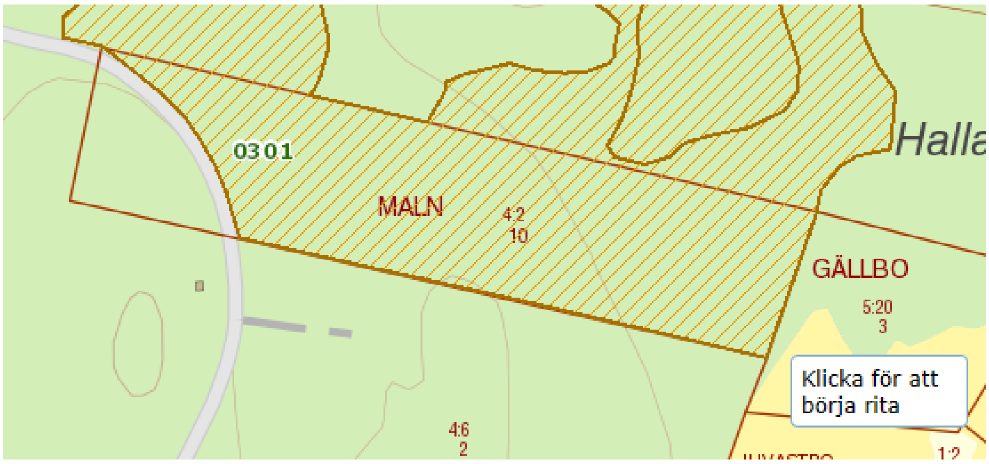

Fig. 16. Example of drawing borders. Start drawing the and with the click of the left mouse button, then proceed with the next boundary point etc. and finish the final figure with a double click. Then press button *"Utför"* to start the calculation.

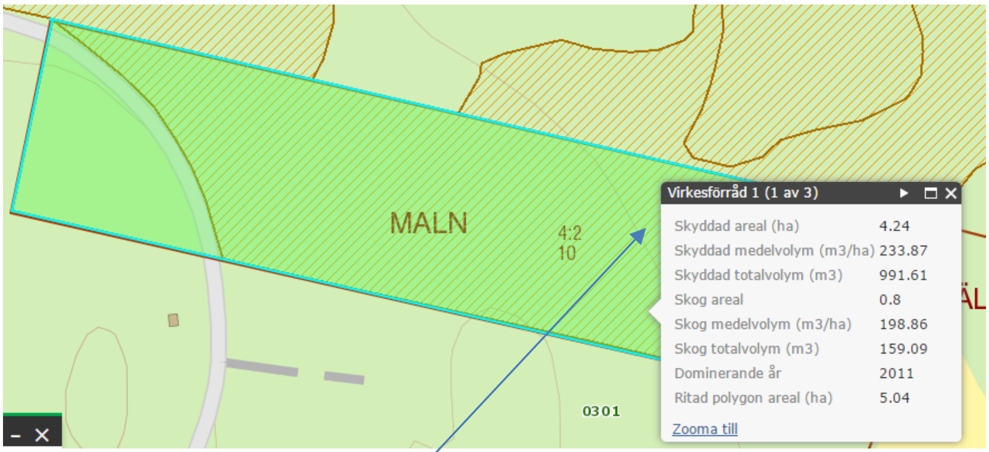

Fig. 17. Example of result from a calculation based on our selected figure.

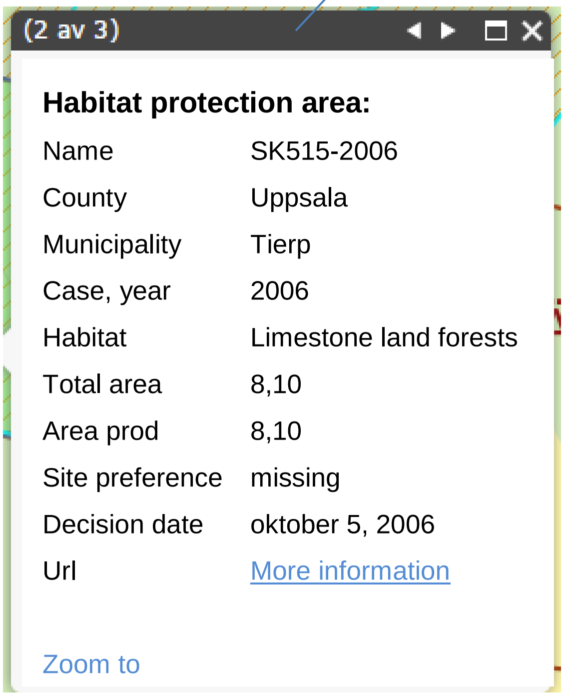

Fig. 18. The figure shows that it is possible to get more information about the protected area through metadata.

6. CONCLUDING REMARKS

6.1 What can be expected

The purpose of this paper was to present how new technology associated with laser scanning enables improvements in connection with property tax assessment, in particular as regards calculating the volume of standing forest (stem volume).

A weakness of the volume estimated by the laser is that this data in some cases has become too old and needs to be updated. Furthermore, tree species and age/site index are in demand variables that cannot be estimated with only laser data from a single time point. An exciting technological development is ongoing, however, with a development that is expected to enable more frequent updates of the volumes. This will be of great importance, even for the Swedish Tax Agency that now has started to use this tool as an aid in the assessment in those cases when the growing forest volume is uncertain or missing. When this volume estimate will be updated at shorter intervals the information produced will evolve from being solely a support to an independent estimate of a property's growing volume without first having to ask this question to the property owner.

As announced in a press release from the Swedish Forest Agency in February 2017, there is a large consensus among the authorities and forest industry concerned on the need for new data. Both the forest industry as well as other societal and environmental interests benefit greatly from the information the maps provide. All participants estimate that the state should keep together the work and ensure the funding, so that the data generated will be open data that can be digitally available for everyone from small forest owners to government and other sectors of society. Then they can also serve as a base for digitization. The goal is to bring about a new laser scanning from year 2018.

Another option is to use point clouds from digital photogrammetry. However, according to Nilsson et al. (2016, referring to Bohlin et al., 2016) when using photogrammetry data trained with the National Forest Inventory plots, the accuracies for stem data will be somewhat lower than with laser data. The reason is that the photogrammetry data contain less information about the tree density.

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BIOGRAPHICAL NOTES

Anders Bogghed is currently working at the Department for Real Property Economy in the Cadastral Services Division of Lantmäteriet (the Swedish mapping, cadastral and land registration authority) as a project manager for forest valuation systems and methods. He graduated with a master degree in Forestry from the Swedish University of Agricultural Sciences, Umeå, Sweden in 1994.

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