SVEASKOG

Report

EVALUATION OF ARBOREAL FOREST WITH LIDAR

SVEASKOG FÖRVALTNING AB – 20210830
VERSION 1.0

Report

EVALUATION OF ARBOREAL FOREST WITH LIDAR

BACKGROUND

Good forest data is a prerequisite for:

- Correct forecasts of products after harvest
- Efficient deliveries to customers
- The right action at the right time
- Follow-up of thinning
- Profitable timber business
- Carbon capture credits

Today, Sveaskog measures with manual methods, uses Forest data from the national Lidar survey, and harvester data for forecasts of stands after thinning. These measurements are then used in conjunction with harvester data to make exchange predictions using imputation.

Getting better data would increase the value of Sveaskog's forest through the changed conditions mentioned above. Sveaskog works with remote data, harvester data and AI to get better data, but at the same time a lot happens with hand-held devices that can be used in the forest for data collection, and we wanted to investigate how accurate data they could bring.

Modern telephones now have Lidar sensors that can be used together with AR technology to make forest measurements. Arboreal is the first company in the world to have such a product on the market and Sveaskog has tested the application Arboreal Forest.

Arboreal Forest is an application available for iOS. It is a digital caliper where you measure diameters and heights in circular sample plots or along line transect. The application has previously been evaluated by Lisa Lindberg at SLU.

After Lisas evaluation, the application has been updated many times and has even more features than before. One function is that it can measure diameter using an active sensor (Lidar). It reduces the individual's influence on the measurement of diameter. In addition, the phones have become better and provide more accurate area estimates. Finally, Arboreal has added a new measurement method. Belt inventory.

Belt inventory is to measure the trees within a certain distance from a line transect. The method is old and was used in the early national forest assessments during 1923 to 1929. Manfred Näslund wrote an article about it as early as 1941.

The method requires that you are several people in order to get great data. Södra has used a similar method to follow up thinnings and has evaluated it in a degree project.

In general, it is difficult to do belt inventory with manual tools because of the uneven ground. In addition, it is difficult to get an exact estimate on the distance from the center line to the center points of the trees to determine whether the tree should be counted or not. Early tests showed that Arboreal Forest was better or equivalent than the manual methods. We wanted to do another evaluation.

The accuracy of the estimate of forest parameters when using a caliper is affected by:

1. Correct area on sample plot
2. Correct diameter of the measured trees
3. Correct height when measuring trees
4. Taper equations
5. Sample design, how representative are the sample plots and do they cover the variation in the stand.

In this evaluation, we have evaluated the diameter measurement, the area measurement, and the total result.

METHOD

Mathias Odén visited stands with planned harvest operations in southern Sweden. He has measured the forests with Arboreal Forest with an iPhone 12 Pro with Lidar. He has walked between 3-5 lines in each planned operation and measured the diameters of the trees and the height of the average trees for each tree species. Each line was on average 132 meters and included 34 trees in average.

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Image 1. Example of visited operation with three belt inventories. The points are from the GNSS locations of the measured trees.

The operations were harvested by harvesters that have been calibrated. The trunks from the harvesters' HPR files have been put together into trees and added to the felling areas and forest parameters have been calculated.

The result has been compared with values from Arboreal Forest and regular planning (referred to as traditional). The measurement method for traditional planning is subjective relascope inventory.

The area calculation depends on the accuracy of the estimate of the length of the line. If the distance measurements are 1% incorrect, the area calculation will be 1% incorrect. To examine the variation and quality of the distance measurements, 20 trees along a line of approximately 121 meters were measured 11 times and the mean and standard deviation were calculated. In addition, the same distance between the trees was measured with manual tools (Spencer Loggers Tape 20 m, Toolmate 50 meters, Laser meter Cocraft HD 400 -2) to see how big the difference was.

We also measured the diameters of many trees and compared the difference with the measurements from the results from calipers and measuring tape. Trees less than 40 centimeters was measured with caliper (Haglöfs DP II). Trees over 40 centimeters were measured with a measuring tape.

RESULT

Table 1. Comparison between results from harvester (HPR), traditional measurements and Arboreal Forest (Belt inventory). Eleven operations were included in the study.

	Harvester (HPR)	**Traditional error**	**Arboreal error**
Diameter (DGV)	27,5 cm	7,8 %	3,8 %
Volume	294 m3sk / ha	13,5 %	8,0 %
Basal area	29 m2	13,9 %	6,5 %
Trees	642 / ha	33,7 %	5,4 %
Average tree volume	0,42 m3fub	17,8 %	8,1 %
Tree species (Pine) % units	37 %	8,9	6,6
Tree species (Spruce) % units	59 %	7,9	6,5
Tree species (Decidous) % units	4 %	2,7	1,9

The error is mean absolute error (MAE) in % for Diameter, Volume, Trees and Average tree volume. The error of the tree species is the average error in % units as sometimes the amount was zero and then the error would reach infinity.

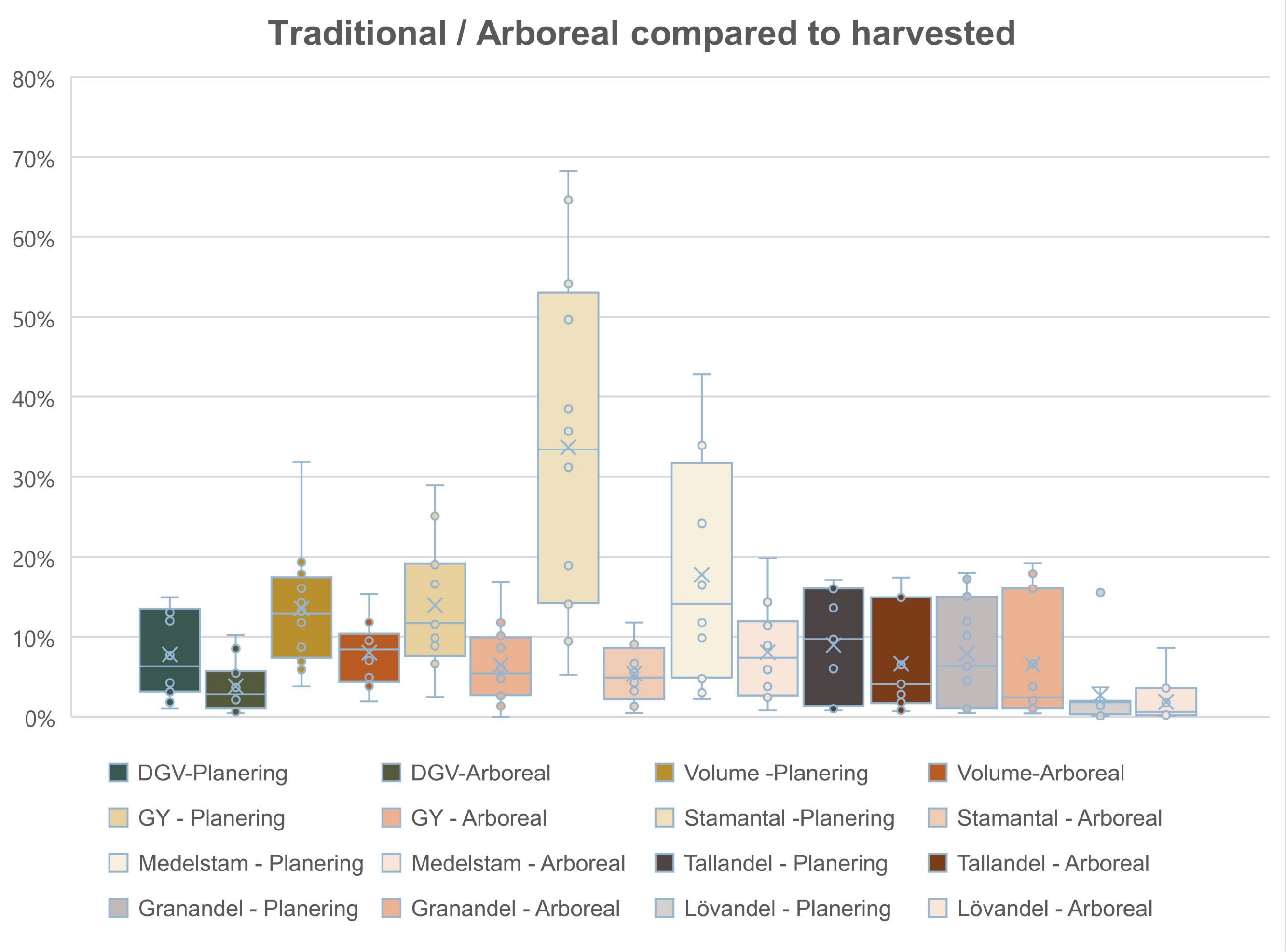


Figure 2. Results from Traditional/ Arboreal compared to harvested data.

Table 2. The bias of traditional tools / Arboreal Forest compared with harvest trees. Eleven areas.

	Traditionell	**Arboreal**
Diameter (basal weighted)	- 1,23 cm (- 4,5 %)	+ 0,84 cm (+ 3,0 %)
Volume (m3sk / ha)	+ 18 m3sk (6 %)	- 4 m3sk (- 1,4 %)
Basal Area	+ 2,0 m2 (+ 6,8 %)	+ 1,0 m2 (+ 3,4 %)
Trees	+ 92 / ha (- 14 %)	+ 25 / ha (+ 4 %)
Average tree volume	- 0,05 (- 11 %)	- 0,02 (+ 4 %)

Table 3. Difference between diameters measured with Arboreal and caliper / measuring tape.

	MAE	Bias (cm)	Average diameter (cm)	Number of trees (n)
iPhone 12 Pro	**4,0%**	**-0,097**	**27,3**	**160**
Not automatic	4,0%	-0,097	27,3	160
iPhone 12 Pro Max	**4,2%**	**0,082**	**25,0**	**176**
Automatic*	4,1%	0,107	21,0	73
Not automatic	4,3%	0,065	27,9	103
Total	**4,1%**	**-0,003**	**26,1**	**336**

** Automatic – the app locates the tree and measures the diameter automatically.*

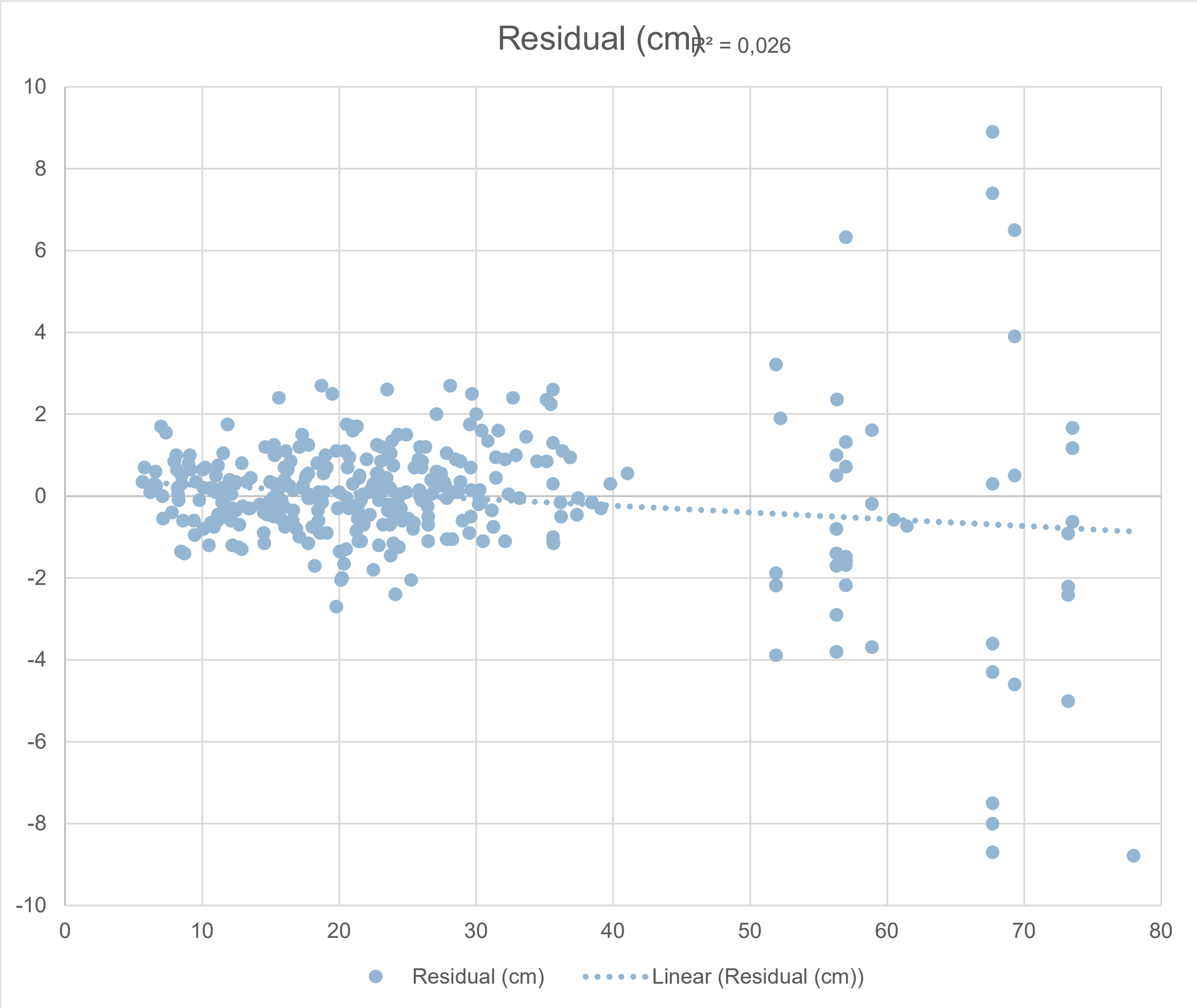


Figure 3. Difference between measurements in centimeters (Caliper / Measurement tape and Arboreal) related to the diameter of the trees.

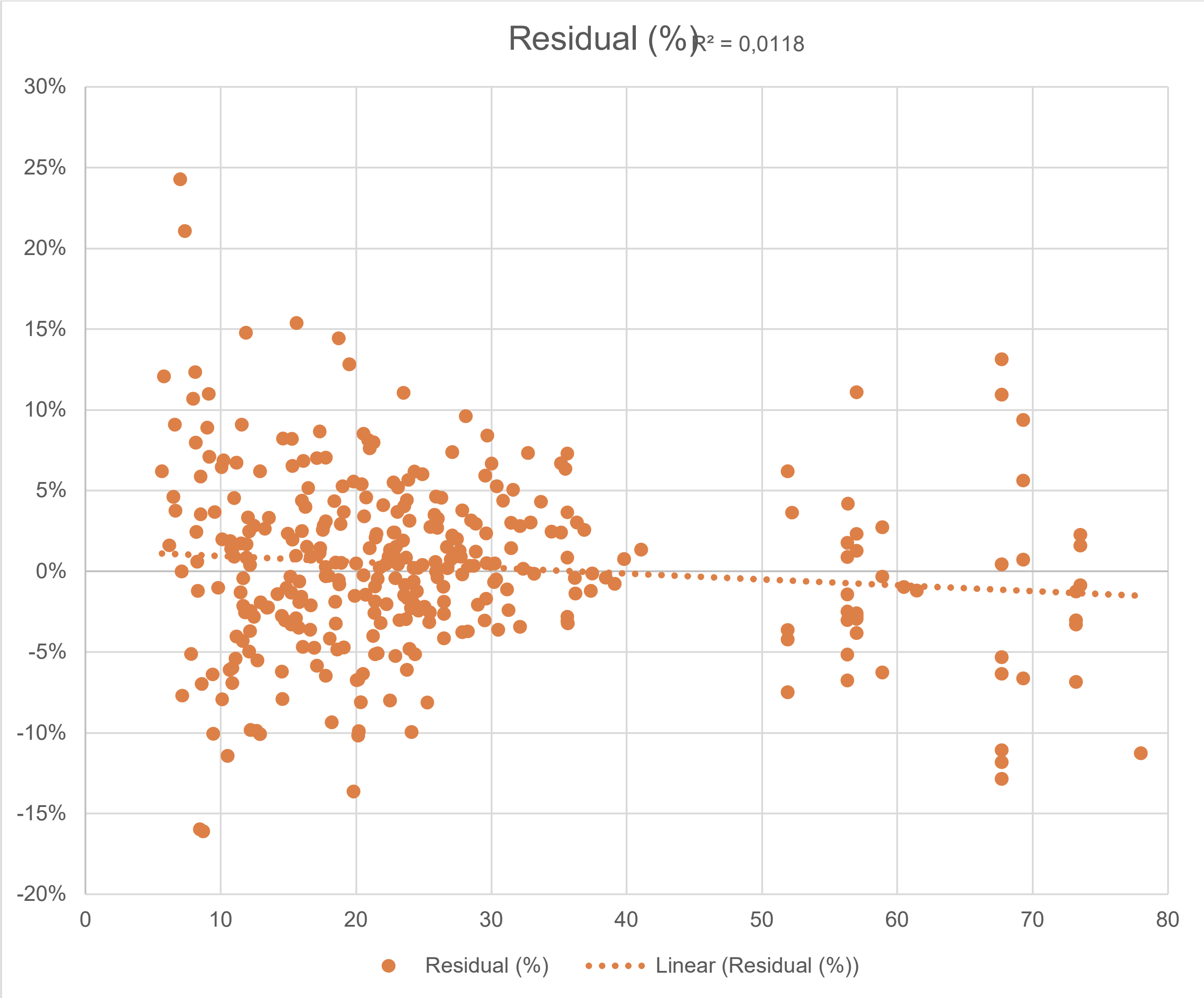


Figure 4. Difference between measurements in % (Caliper / Measurement tape and Arboreal) related to the diameter of the trees.

Table 4. Distance between trees along a transect that was measured 11 times with Arboreal Forest compared to alternative methods.

Distance between trees	Arboreal average (m)	Arboreal Standard deviation (m)	Taper (plastic)	Taper (Metal)	Laser
1 – 2	16,4	0,198	16,30	16,31	-
2 – 3	4,19	0,035	4,19	4,17	-
3 – 4	4,51	0,032	4,52	4,49	-
4 – 5	11,65	0,131	11,69	11,60	-
5 – 6	6,63	0,053	6,66	6,62	6,64
6 – 7	4,78	0,044	4,84	4,79	4,79
7 – 8	20,97	0,15	20,97	20,97	-
8 – 9	3,13	0,036	3,12	3,07	3,12
9- 10	2,63	0,036	2,66	2,60	2,69
10 – 11	8,72	0,064	8,77	8,71	8,76
11 – 12	4,10	0,066	4,08	4,06	4,10
12 – 13	8,93	0,073	8,98	8,93	8,92
13 – 14	3,17	0,037	3,16	3,11	3,19
14 – 15	3,77	0,06	3,81	3,78	3,85
15 – 16	6,20	0,044	6,20	6,16	6,23
16 – 17	3,35	0,027	3,44	3,40	3,42
17 – 18	1,74	0,017	1,77	1,72	1,78
18 – 19	3,15	0,03	3,23	3,16	3,17
19 – 20	8,86	0,07	8,85	8,81	8,88
1-20	121,42	0,608	-	-	-

Data is missing for some trees; they were measured two months after the other measurements. Then some of the physical markers had disappeared.

DISCUSSION

The measured values for Arboreal Forest are generally better than using traditional methods (Table 1). However, the difference in the proportion of tree species is small and since it is based on a few stands, no major conclusions should be drawn from these.

The number of trees per hectare reflects how correctly the area is measured in the app. The difference is very small and then you must remember that some trees are left during the felling that have been registered in the Arboreal survey but not in the production data. The instruction is to leave the deciduous, old and coarse trees. This means that we expect that measurements carried out before felling should overestimate the number of trunks, basal area, diameters and proportion of non-deciduous trees. This is the case for both the traditional measurement and the measurement with Arboreal Forest.

The diameter measurement on individual trees compared to caliper measurements has a systematic error of less than 0.1 mm and an average absolute error (MAE) of 4.1% (Table 3). The error in centimeters has a positive relationship with diameter (Figure 3). However, we see that the percentage error has no correlation with increased diameter. The cause of the diameter error is mainly caused by the fact that trees are often oval, the coarse trees we measured were all oval. When we measure trees from different directions, the difference between manual methods and with Arboreal became very small. The systematic error (bias) was extremely low, it will imply that under practical conditions where several trees are measured, the user will get good average values of diameter and thus basal area.

In general, diameter measurements with Arboreal Forest and Lidar give good results.

The tree species measured in these experiments were Pine, Spruce, Birch, Ash and Aspen. Since these are optical measurements, the bark structure will be able to influence the measurement of diameter. For most tree species, it will not cause any problems.

To see how stable the area measurement becomes, the line transect was measured 11 times. See table 4. The spread is very small. The standard deviation is around 1% of the measured distance. Manual methods gave similar results. The manual methods are also prone to error, it can be seen that there are differences between using plastic and metal measuring tapes and laser distance meters.

The fact that the standard deviation for the whole line was 0.5% indicates that over further distances the results will get better. That is caused by the fact that sometimes there is a drift that sometimes is positive and sometimes negative. When you walk for a while, this differences will take out each other.

We are surprised by how good the results were from the distance measurement and thus the area of the sample plot.

With the small difference between the number of trees per hectare between Arboreal and the felled stands and that the distance calculations were very good, the belt assessment feels like a stable method of getting the correct area on the sample surfaces.

Incorrect estimates also depend on the sample design. Anton Grafström has developed a web tool to be able to simulate different sample design and how it affects the result. There you can compare different layouts of the test surfaces and the methods circular plots, belt and relascope inventory. However, the measurement methods have no errors in the simulator, but we know that measurements with relascopes are difficult and are a major source of error. A comparison between different forests and sample designs can be found in Appendix 1.

From having done some simulations, we see that the belt inventory has a low standard deviation if it has a proper direction and captures the variation in the stand.

Training may be required to get good measurements with Arboreal Forest. We experienced that Mathias performance became faster and more accurate after the first days.

To get better forest estimates, Arboreal Forest, belt inventory with Lidar is a good method. To get reliable results, use 3-5 lines with a length of 100-150 meters depending on the size of the stand and its variation.

We recommend using the belt inventory method instead of circular surfaces because it is easier to implement, the AR technology is more stable when walking along a line and that you cover different parts of the forest in a good way.

Suggested improvements of the app:

- Be able to vary the width of the line. In homogeneous forests where the trees stand in rows, the width plays a greater role. In really sparse forests, it would be good with a width greater than 4 meters.

- Be able to turn the line to implement the method in smaller forests and to avoid areas that shouldn´t be included in the survey.

SVEASKOG IN BRIEF

Sveaskog is Sweden's largest forest owner and sells sawlogs, pulpwood and biofuel to customers, primarily in the pulp and paper and sawmill industries.

Sveaskog also works with land transactions and develops the forest as a venue for hunting, fishing and other nature-based experiences. Sveaskog is the Swedish market leader within forest regeneration and seedlings through Svenska Skogsplantor.

Report

The forest and its assets are Sveaskog's core business. Conducting forestry operations and developing new business opportunities and applications for wood raw material, wood products and forest land are a major responsibility. Sustainable development permeates every aspect of Sveaskog's business.

A tree that is planted today will be harvested in 60–120 years. The growing forest and production of wood raw material make a substantial contribution to counteract climate change.

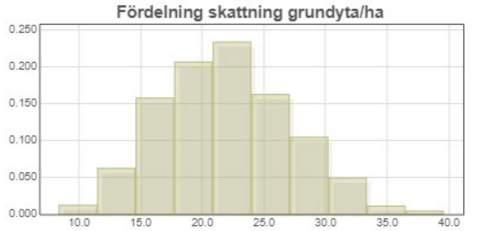
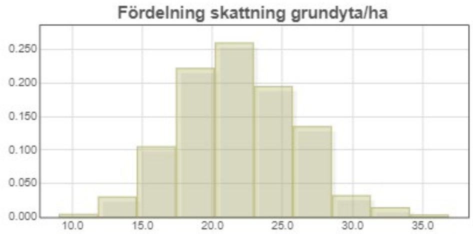
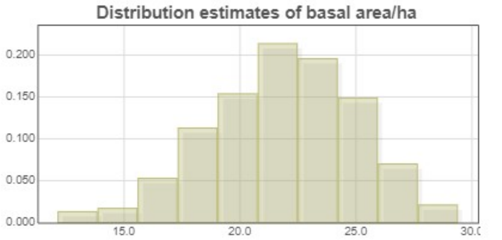
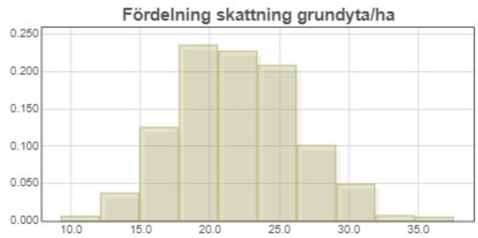
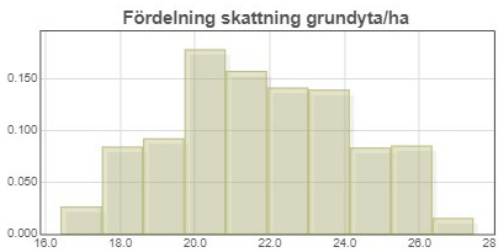
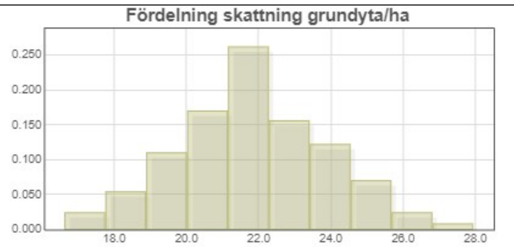
Sveaskog had sales of SEK 6.597 million in 2020 and in average 827 employees throughout Sweden.

Sveaskog is owned by the Swedish state. The main geographic market is Sweden.

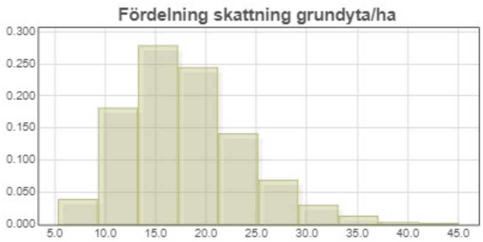
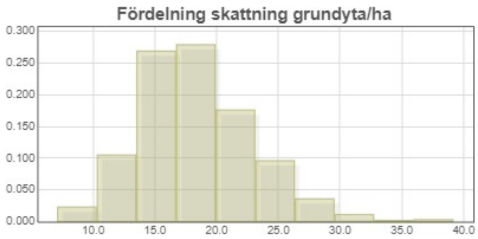
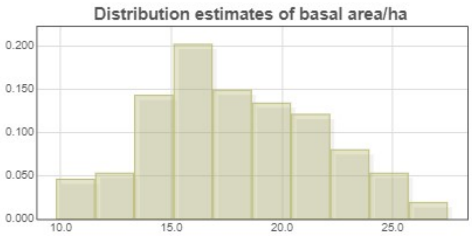
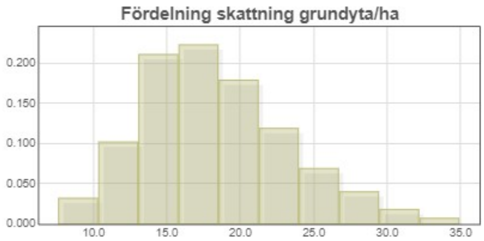
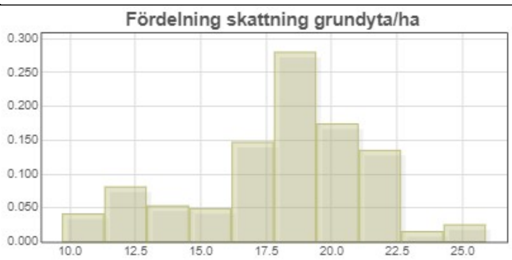
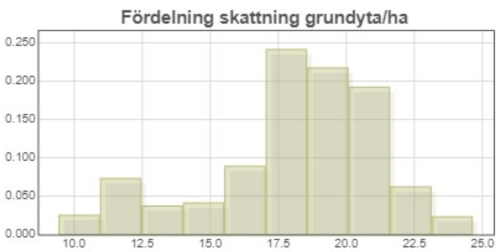
BILAGA 1 – SAMPLE DESIGN.

Sveaskog's instructions state that the planner must lay out 6 subjective relascope sample plots in stands that are less than 6 hectares in northern Sweden. We simulated different sample designs in two different stands. The tool is developed by Anton Grafström and available at: http://www.antongrafstrom.se/simulator/en/

Name	Image	Description
Population 4 - Gradient		An uneven mixed forest with large variation. Basal area 21,91 m2, Diameter (Basal weighted) 27,68 cm. Volume 173 m3
Population 6 - Clustered		An uneven mixed forest with large variation. Basal area 18,2 m2, Diameter (Basal weighted) 24,6 cm. Volume 139,8 m3

Method	Result (Basal area m2 / ha)	Average (21,91)	Standard deviation
6 circular plots. 8 meter radius. Random.		21,98	5,23
10 circular plots. 8 meter radius. Random.		21,93	4,17
10 circular plots. Systemtic design.		21,88	3,16
6 Relaskopytor. Random.		22	4,41
Belt inventory 3 lines. 4 meter width.		21,82	2,4
Belt inventory 3 lines. 5 meter width		21,85	2,05

Population 4. Gradient. 1000 simulations.

Method	Result (Basal area m2 / ha)	Average (18,2)	Standard deviation
6 circular plots. 8 meter radius. Random.		18,1	5,94
10 circular plots. 8 meter radius. Random.		17,42	4,63
10 circular plots. Systemtic design.		17,99	3,16
6 Relaskopytor. Random.		18,37	4,99
Belt inventory 3 lines. 4 meter width.		18,07	3,34
Belt inventory 3 lines. 5 meter width.		18,11	3,16

Population 6. Clustered. 1000 simulations.