Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Annual reporting based on periodic inventory data can be improved with growth simulations and harvests based on RS

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Swedish EPA

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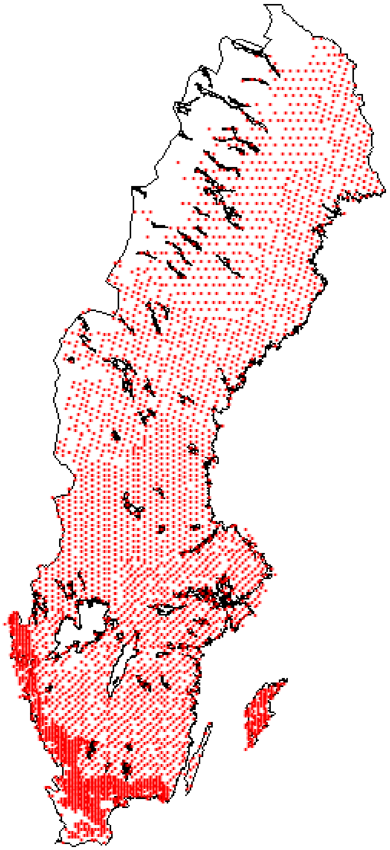
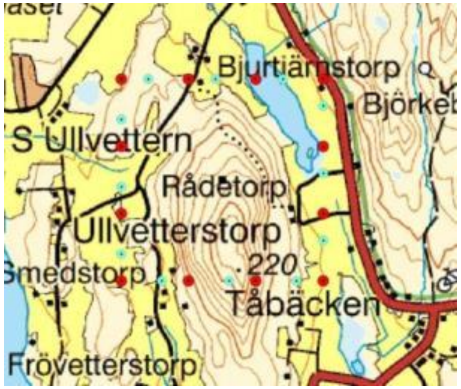
At JRC Technical LULUCF workshop 2024

Swedish LULUCF reporting –LB



- Sweden uses design-based (probability sampling) inventory (NFI) to assess changes in Living Biomass (LU, Dead Wood, Soil Organic Carbon)
- Carefully measure on the plots – then the uncertainty of our estimator arises from that a sample and not the entire population is measured. No bias and the accuracy can be controlled by sample size and design
- Periodic design, accuracy change in LB: 3 Mton CO2/yr, <2%
- All land inventoried and it is simple to match change in living biomass to land use/ land use change and trace back to 1990



Periodic survey, not only the LU Matrix

Spatial explicit according to IPCC 2006 = spatially referenced

- Periodic survey is efficient to measure change in stock
- Possible to consistently trace LU and LU-change from 1990 and onwards
- And let land stay in conversion class for 20 years (but its annual changes in the matrix)
- Possible to match change in LB to LU/LU-change
- Annual LU-change here 0.13%

[kha]	F	C	G	W	S	O	Initial
F	28114,45	1,27	2,18	0,00	9,73	1,39	28129,02
C	4,06	2843,68	4,45	0,00	5,13	0,00	2857,33
G	4,12	3,50	495,82	1,06	0,00	0,00	504,50
W	13,65	0,00	0,00	7419,30	0,00	1,23	7434,18
S	3,54	0,00	0,00	0,00	1888,69	0,00	1892,24
O	1,79	0,00	0,00	0,52	0,00	4313,96	4316,28
Final	28141,62	2848,45	502,45	7420,88	1903,56	4316,58	45133,54

Why not using RS to assess LU?

- Uncertain – sometimes not easy to assess LU on the ground
- Risk of bias – artificially overestimate
- No statistically straightforward way to match carbon pools with LU

Swedish LULUCF reporting -LB

- Five permanent panels/cycles/omdrev established 1983-1987 (ca 5 x 6000 plots) on all land
- Green is measured and blue is interpolated (linear if no harvest)
- Only one panel is inventoried 2023 for submission 2025 and years 1990-2019 are fixed
- The stock difference method reports a trend
- Year 2023 not fixed until 2027
- <u>How to get an acceptable estimate of the fixed 2023 removal already in submission 2025?</u>

Omdrev	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
1983	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023				
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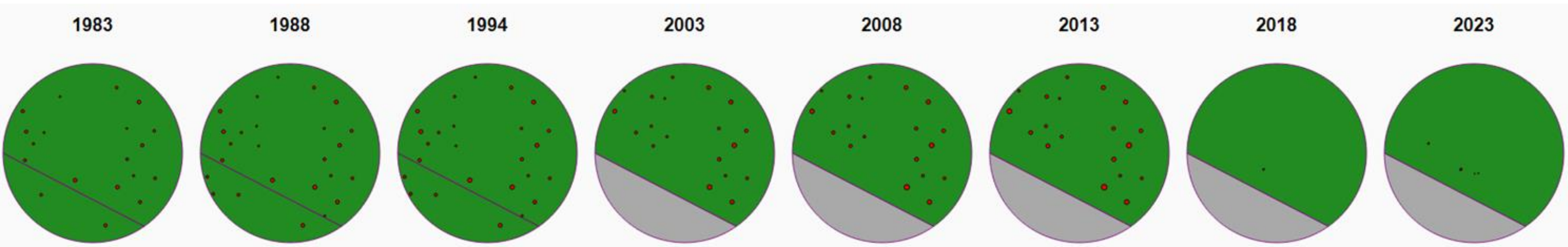
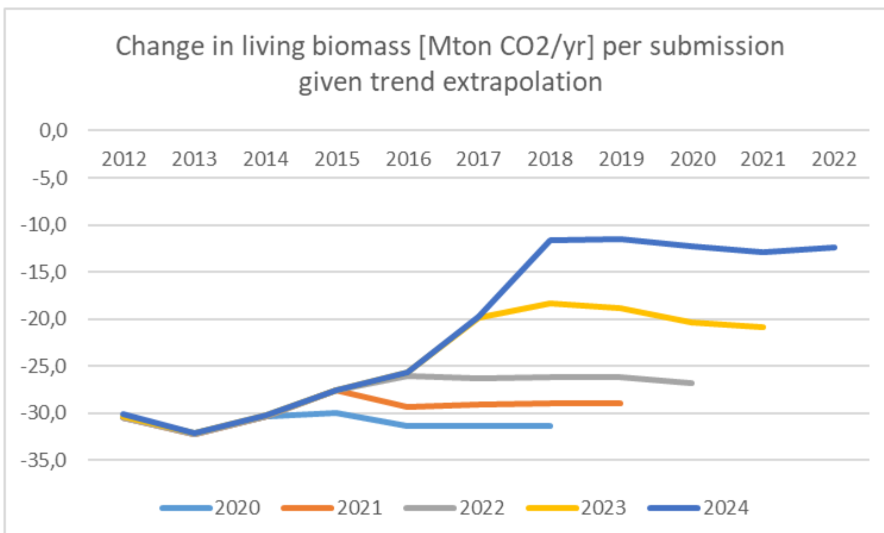


Problem Swedish LULUCF reporting

- For cycles without a full record, trend extrapolation has been used based on the trend of the five year before (made per cycle and LU category 5 x 36)
- When re-measured the extrapolated value is dropped
- The trend extrapolation has been suggested by the ERT
- This approximation has worked until 2018 when we got the drought, that changed the trend
- The reported net-removal (excluding small trees) has changed between submissions
- We simply have to improve the preliminary data before fixed in 2027



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Swedish LULUCF reporting -LB

To project five years:

- Growth, In-growth, Final felling, Thinning, Other harvest, (Cleaning), Mortality

Data sources/ approaches:

- Start values of tree-, stand- and site conditions
- Simulate using the Heureka model
- AI (machine learning): we can train models using 2013-2018; 2014-2019; 2015-2020; 2016-2021; 2017-2022 and 2018-2023, respectively
- We can identify final felled plots in time through changes in spectral signatures using satellite images to 2023
- Other sources the NFI, Forest agency, remote sensing,…

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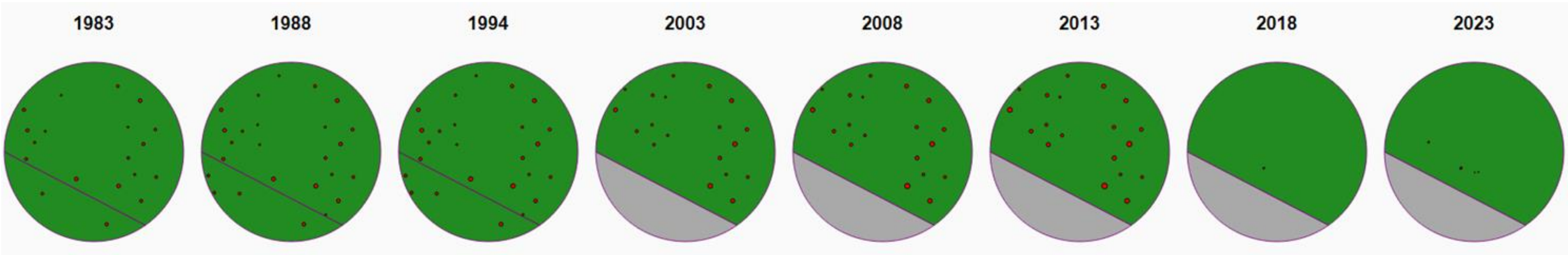
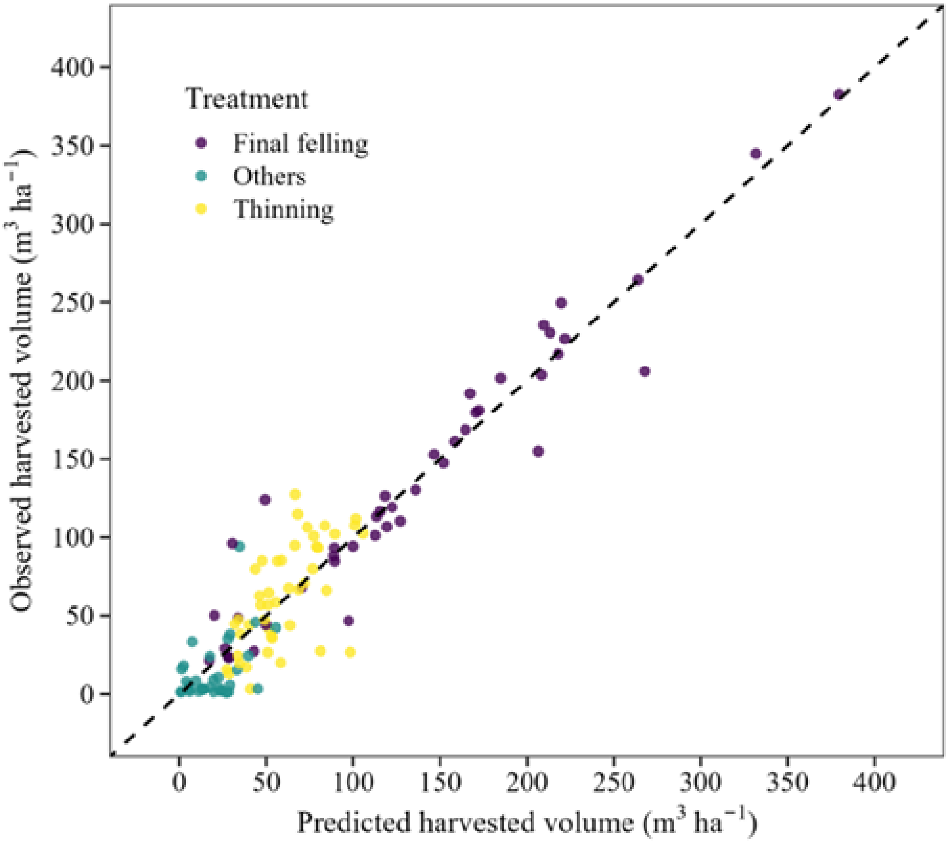


Harvests

Remote sensing:

- Check <u>if a plot is harvested or not</u>, using spectral signatures from Sentinel 2 (annual histogram matching model from 2017 using near infrared, short wave infrared and visible bands) (accuracy between 80-90%)
- <u>Given</u> harvest, we predict the amount harvested using satellite information (Google Earth Engine) and NFI plot data, (figure)



Final felling R2=0.93
RMSE=23 m3/ha

Thinning R2=0.41
RMSE=25 M3/ha

Others R2=0.12
RMSE=19 M3/ha

Machine learning-LB

Machine learning is a field of AI focusing on developing algorithms and models that can learn from and make predictions or decisions based on data

Plus

- Handle huge amounts of data
- Improve when exposed to more data.
- Flexibility: Machine learning algorithms can be adapted to a variety of applications

Minus

- Interpretation difficulties: "black boxes" where it can be difficult to understand why
- Requires large amounts of good quality data.
- Overfitting

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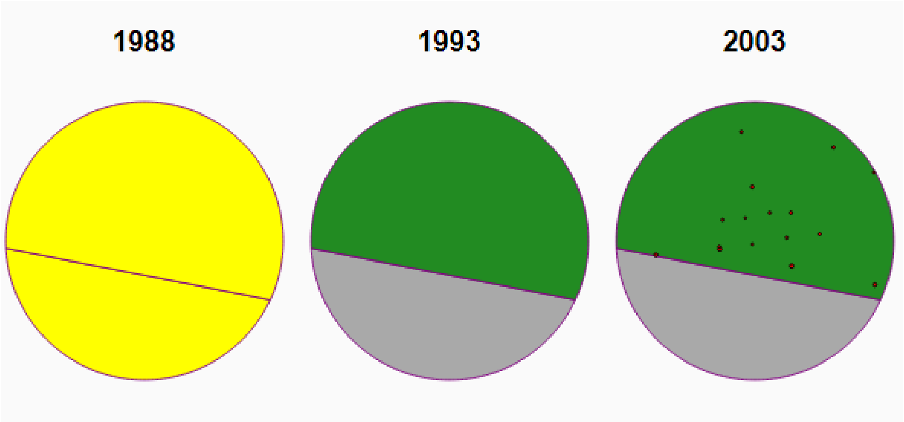
Machine learning-LB

Using Machine learning we predicted:

- Growth for “permanent” trees “normal growth” considered R2=0.99
- Ingrowth, trees that becomes 100 in dbh?



- Final felling, thinning, other harvests, mortality similar accuracy as for the parametrically approach –some ideas to improve to reduce bias. E,g, to handle “negative harvest” (the model indicates harvest but no harvest existing)

Machine learning-LB

Machine learning was used to predict stock (LB) five years ahead for cycles 1983 and 1987. Difference between observed and predicted for cycle 1983 was estimated to -0.19 to -0.87%, 2018-2023 and the corresponding for cycle 1987 was -0.12 to -0.46%, 2017-2022. The model is trained on two time periods and to avoid overfitting to the data, "early stop" was used. <u>For change in stock the difference may be up to 5-9 Mton CO_2/year</u>.

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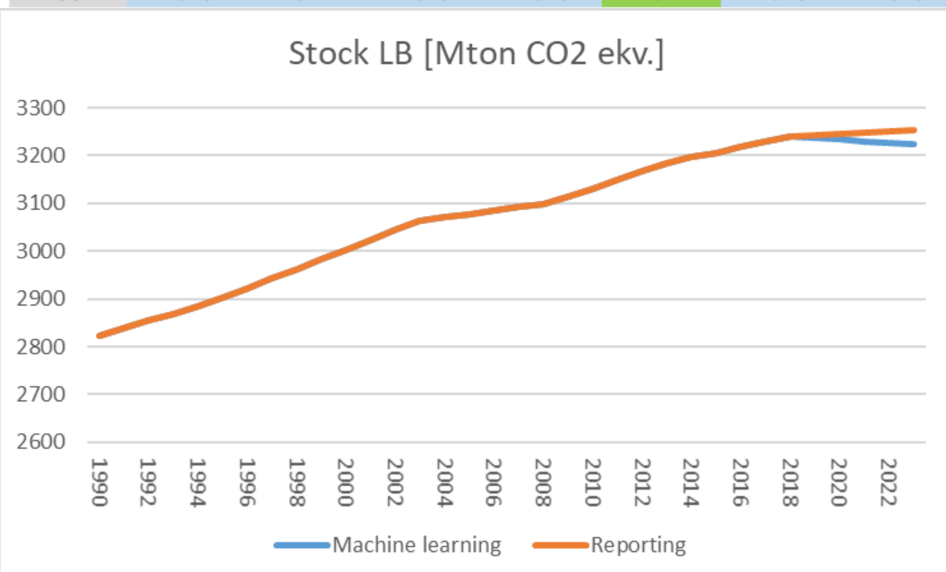

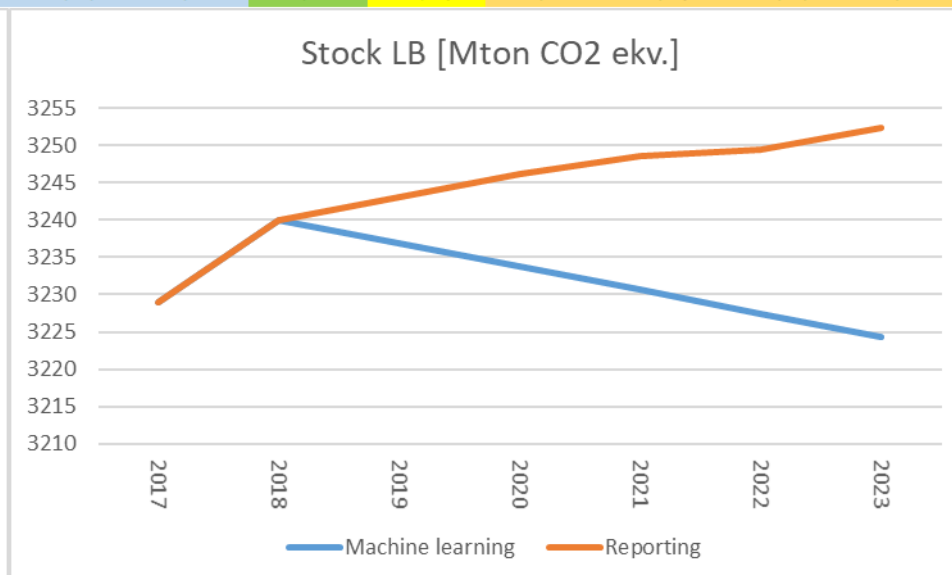

Refers to cycle 1983. current challenge is modelling harvest

Added values and thoughts

Annual data

Machine learning or modeling might be used to obtain annual data. This is probably no problem for interpolation of sample data but we do not know much about bias in extrapolation. (Sweden will drop extrapolated data when re-measured in the LULUCF-reporting)

Annual data

Several stakeholders are involved in model assisted approaches. A model assisted approach probably increases the accuracy if the model to support the estimation is following probability sampling with a design based inference approach. This model can be based on the NFI calibrating auxilliary information from remote sensing

- The NFI data is the driver –not from a subjectively selected site
- The model has to be annually updated since the relationship NFI/RS will change
- We have to evaluate bias
- We lose the link between variables like LB and LU and traceability
- Difficult to choose RS source and estimates do not become consistent over time
- The method probably hardly improves reporting at the national level (for Sweden), but for regions and locally model-based approaches can be used (model-based estimators biased but good enough)

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Swedish Environmental Protection Agency is responsible for the Swedish LULUCF reporting

SLU researches and reports LULUCF. Reporting based the National Forest Inventory and the Soil Inventory. Expertise within inventory and sampling, mathematical statistics, remote sensing, soil, and planning (Heureka).

https://www.slu.se/globalassets/ew/org/inst/sresh/om-institutionen/dokument/annualreport2023-webb.pdf

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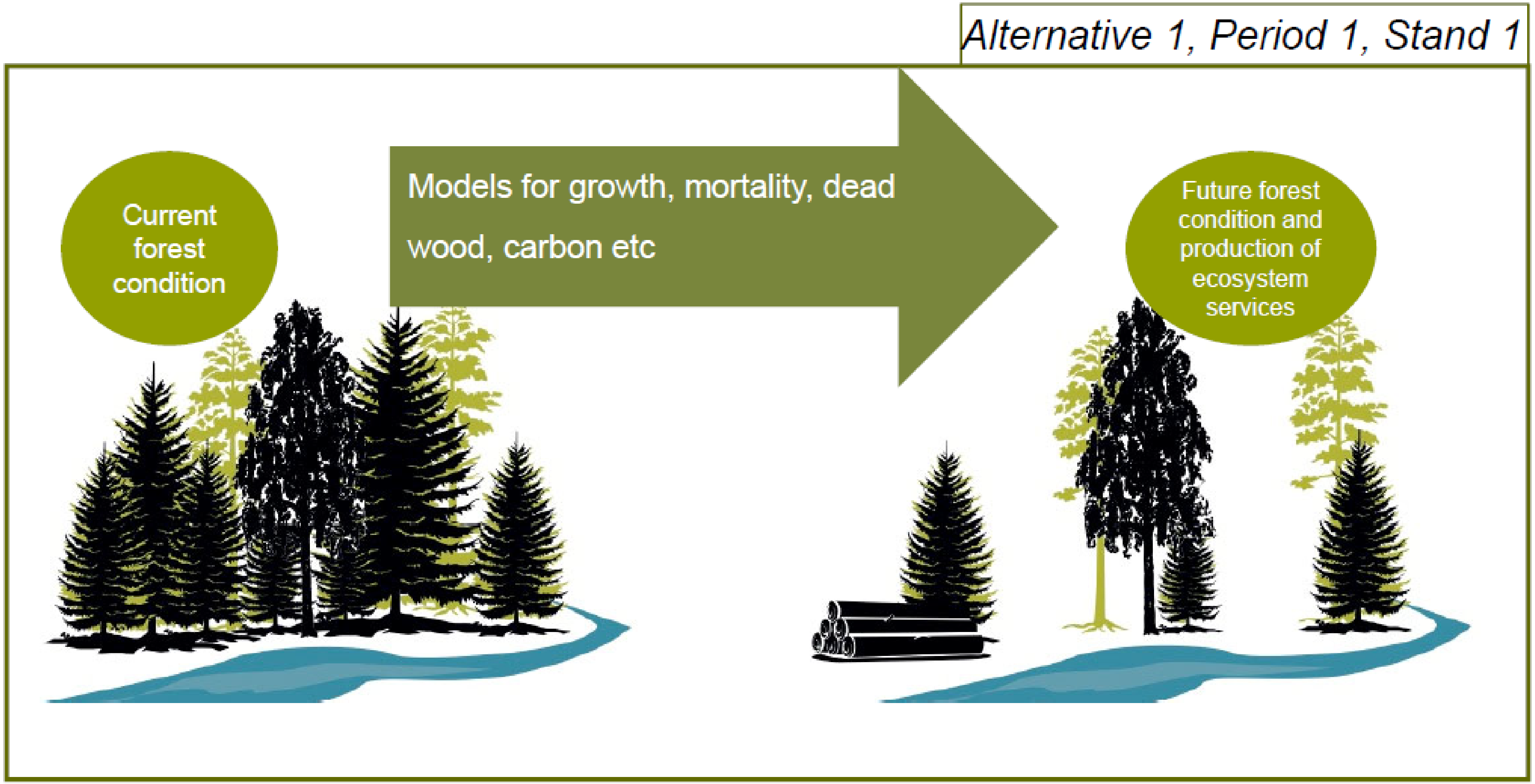
RegWise simulation model

Heureka



Heureka RegWise empirical model

Heureka:
- Is an empirical model
- Volume for five cycles were projected five years (Figure)
- Problem with in-growth for a short period?
- Possibility to adapt growth to normal growth and harvest intensity
- Mortality can be modelled

Figure) Predicted volume using Heureka and measured on the plots (red=if perfect correlation)