Skogssällskapet

Slutrapport

Projektrubrik: Mapping risk for wind and snow damage with state-of-art remote sensing in Sweden

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Populärvetenskaplig sammanfattning

Vind och snö är två av de främsta orsakerna till skogsskador i Sverige. Klimatförändringarna väntas öka skogens sårbarhet för både stormar och snöbrott, särskilt om skogsskötseln inte anpassas. Förbättrade metoder för att kartera känsligheten för skador i skogslandskapet gör det möjligt att bättre anpassa skogsskötseln till framtida klimatpåverkan.

I denna studie har vi för första gången tagit fram generella känslighetsmodeller för vind- och snöskador anpassade för svenska förhållande. Modellerna baseras på empiriska skadedata från SLU Riksskogstaxering och heltäckande fjärranalysdata. Vi skapade 4 olika modeller separat baserade på fält- och fjärranalysdata, och för norra respektive och södra Sverige. Utöver skogliga attribut, testades vädervariabler, information om beståndgrannskap och terränghöjd. Vi utforskade vilka fältbaserade och fjärranalysbaserade variabler som är dom viktigaste för skaderisken och jämförde olika modeller. För att demonstrera våra fjärranalysbaserade modeller skattade vi känslighet för vind- och snöskador över utvalda testområden, som visualiserades i form av riskkartor.

Våra resultat visade att det är möjligt att ta fram modeller för skogens känslighet för vind- och snöskador med acceptabel noggrannhet. De bästa modellerna inkluderade en kombination av variabler om skogens struktur och trädslag, vind och/eller snöförhållanden och terränghöjd. Som förväntat hade de fältbaserade modellerna lite högre skattningsnoggrannhet jämfört med de fjärranalysbaserade modellerna. Modeller för norra Sverige hade högre noggrannhet än de för södra Sverige, vilket kan bero på den större variationen i skogen i söder.

Resultat från de fältbaserade modellerna visade att ökning i andel av contorta och gran hade en positiv effekt på skadesårbarheten, såväl som ökning i trädhöjd, höjd över havet och tid sedan gallring. I de fjärranalysbaserade modellerna var laservariabler som beskriver skogens struktur viktiga, tillsammans med information om trädslag från heltäckande kartor. Ökning i snödjup eller snölast ökade skadesårbarheten i norra Sverige, medan ökning i höjdskillnader mot angränsande bestånd ökade sårbarheten i södra Sverige. Minst en variabel om maximal vindhastighet från en viss riktning inkluderades i alla modeller.

Våra fjärranalysbaserade modeller kan appliceras över hela Sverige i form av riskkartor, som möjliggör utvärdering av förekomst och fördelning av skadesårbarhet på bestånds-, regional och nationell nivå. Genom att lokalisera potentiella områden med hög sårbarhet kan skogsägare och andra beslutsfattare lättare anpassa sin skogsförvaltning för ett förändrat klimat. Förutom förebyggande åtgärder kan riskkartor också användas för att hitta skadade träd efter väderevent. De fältbaserade modellerna kan dessutom implementeras i skogliga beslutsstödsystem Heureka för att stödja den långsiktiga skogliga planeringen. Projektet genomfördes i samarbete mellan SLU, LUKE Finland och Skogsstyrelsen.

Resultat

The main aim of the study was to develop first empirical model for wind and snow damage vulnerability with help of remote sensing and National Forest inventory plots (NFI). Challenges in damage vulnerability modelling is that both damaged and not damaged forests can have similar characteristics (i.e. forest with high risk may never get damaged). In addition the unbalance in number of damaged and not damaged plots, and the fact that the wind and snow damage category is combined together by NFI, are challenging the modelling process.

We succeeded creating empirical models for wind and snow damage vulnerability to Sweden. The relationship between forest, weather and other variables and the damage vulnerability was modelled using presence-absence data from Swedish NFI plots i.e. damaged/not damaged, total over 40 000 plots from 2010-2022 (Fig 1). Final logistic regression models were created based on 1) NFI data and 2) remote sensing data. Models included also weather and terrain data. Fig. 2 shows a Illustration of the process of creating remote sensing based models and maps. We created separate models for north and south to be able to better take account the geographical differences in damage vulnerability (Fig. 1). Our results showed that all best models combined information on forest structure, tree species and weather, and height above sea was important in most of the models (Table 1). In NFI based models proportion of contorta and spruce had positive effect for damage vulnerability, as well as tree height, mean elevation and time since thinning, which is not available as remote sensing variable. In remote sensing based models laser variables describing forest structure were important together with tree species information. Increasing snow depth or snow load increased damage vulnerability in both north models, as well as increased height difference with neighboring stand in the south models. At least one variable describing maximum wind speed from certain direction were included to all models. NFI based models showed slightly higher modelling accuracies compared to remote sensing based models as well as north models compared to south. This was expected since NFI data is using direct field measured forest variables, and variation in forest structure in higher in south than north. The level of our modelling accuracies are moderate and acceptable and similar to earlier studies. Here we succeeded to create first empirical nationwide models for wind and snow damage vulnerability and got valuable information about different variables connected to damage vulnerability. The remote sensing based models can be used to create nationwide damage vulnerability maps, when the NFI based models can be imported into Heureka forest decision support system to support forest management planning.

To demonstrate the RS based models as map products the “damage vulnerability maps” were created over 3 test areas in Sweden, one in north and 2 in south (See Fig 3. example of Study area north). There is high interest to create similar maps over the whole Sweden. Damage vulnerability maps enable evaluation of abundance and distribution of damage vulnerability in stand, regional and national level. With help of maps the forest owners can more easily detect the regions and stands with high risk for damage and by that to take damage vulnerability better account in their decision making and forest management. In addition to preventing actions, riskmaps can also be used for finding damaged trees after weather events, as has been already done in Finland. It is good to remember that when these kind of models and maps are indicating areas with higher and lower vulnerability for damage, it does not mean that certain low risk areas can not get damaged or that high risk areas will be damaged in the future.

The further research questions raised during the project and final workshop included; how to improve models especially south with higher variation in forest structure, developing alternative remote sensing based models excluding climate information (focus on forestry variables effecting damage risk), improvements in predictor variables like more accurate tree species and change detection data, adding more damage data in the future, and comparison between empirical and mechanistical damage risk models.

During the project we have had weekly meetings with the project group, including SLU and LUKE, and periodic follow-up meetings with Swedish Forest Agency. In addition, Dr. Susanne Suvanto from Luke Finland made a researcher visit to SLU in March 2024 and presented her research in a department seminar. Similarly project leader Inka Bohlin visited Luke in Helsinki Finland April 2025 presenting both this project and other active work on-going in SLU for Luke researchers (Fig. 4). This new collaboration with LUKE has already led for new application aiming to improve the Nordic collaboration in forest damage modelling.

Målbeskrivning

We started in the autumn 2023 with the processing of NFI (National forest inventory data) and remote sensing data over covering whole Sweden. Also the newest weather data from SMHI was ordered, which was good since we got the test a totally new variable "snow load". First, we explored the relationship between the true forest variables (such as effect of tree species or tree height) and damage vulnerability in NFI data, including also spatial neighborhood. Based on this and earlier knowledge on damage risk (e.g. exploring the Finnish models) we then created sets of different predictor variables from remote sensing and weather data to describe damage vulnerability. Over 120 variables were created. Then both correlation analysis and regression models were created to find suitable variables for predicting damage risk. Also the time difference between remote sensing data and NFI field observation, differences in geographical locations of damage data, and effect of large storms were explored. Findings were taken account when creating the final datasets for damage modelling. Before the summer 2024 we got the final sets of predictor variables and created first models to predict vulnerability for wind and snow damage. Model creation continued all the way until spring 2025 due the of lack of resources (lost research engineer) and problems found in some remote sensing variables during prediction phase. Challenges with remote sensing data processing and modelling are typical and expected. Final models were created using a) only NFI data, b) only remote sensing data. Final models used for prediction was created using logistic regression. When best models were selected comparison between NFI based and remote sensing based models was done, as well as between north and south (Table 1). In spring and summer 2025 best models were used to predict wind and snow damage vulnerability maps over 3 selected study areas in Sweden (Fig 3). Final project results were presented and discussed in workshop in May 2025 together with Forest Agency and Forest damage centre.

The project followed quite well the milestones set for the progression, including also the financial part (minor differences in all categories). Weekly and monthly communication with LUKE and Forest

Agency continued successfully during whole project ending with planned final seminar. Also the other communication activities and the research visits between SLU and LUKE were successful.

Even though the final project results were slightly delayed we are happy for the final results and project implementation. The publication of maps from the test areas openly for testing, and submitting the scientific article will be done autumn 2025 as well as some final communication.

Kommunikation och nyttiggörande av resultat

Project progress and results have been discussed with external stakeholders and forest companies e.g. during the periodic forest damage centre reference group meetings and personal meetings with Forest Agency, annual Forest damage centre conference 2024, and PSG- meeting (national network of forest remote sensing and forest planning). Preliminary scientific results have been communicated in the international ForestSat conference in New Zealand September 2024 (Conference is focusing on scientific results and applications in Forest remote sensing). In addition, project was detailed presented and discussed during Inkas visit in Luke in Helsinki Finland for Lukes researchers in April 2025.

In May 7th 2025 was hold an workshop together with SLU researchers, Forest Agency, SLU forest damage centre, SLU forest monitoring program Skog, and Susanne from Luke Finland (Fig. 5). Workshop included hybrid-seminar about project results (circa 25 participants) and deeper discussion afterwards (limited group of circa 10 people) on the project results, their applicability, limitations, further research needs and next steps towards national wind and snow damage vulnerability maps. Participants were interested and happy for the results and Forest Agency was interested to test the maps in practice, in addition SLU forest damage centre lifted the possibility to participate for financing the future national maps.

Currently we are writing a proposal for SLU forest damage centre for creating maps over the whole Sweden based on our results and also about fitting alternative models using only forest based data (excluding climate effect), that was discussed in the workshop. During the autumn 2025 the maps for test areas will be made available through Skogsdatalabb (platform/project of SLU and Forest Agency) for everyone for testing. Final results will be communicated via newsletters, and seminar for the practical users using Forest damage centre’s Christmas seminar for monitoring projects/forest datalab) and in January in the Forest damage centre annual conference. Also the NFI based models produced in the project will get in use, since they will be integrated into Heureka decission support system during the winter 2025-2026. Finally the scientific article will be submitted for international pe-revied journal before the end of the year 2025.

Bilaga till slutrapport

Bilaga 1