Annual report

SLU Forest Damage Centre 2021-2022

A summary of the centre's first two years

About the SLU Forest Damage Centre (SLU Skogsskadecentrum)

The SLU Forest Damage Centre started officially in 2021 as an assignment of the Swedish government. The centre produces knowledge to protect forests against forest damage caused by game, insects, fungi, storms, fires, drought and more. The mission also includes analysing the risks and consequences of forest damage.

Read more: www.slu.se/forestdamagecentre

Annual report - SLU Forest Damage Centre 2021-2022
Year of publication: 2023, Uppsala
Editor: Katja Fedrowitz and Cajsa Lithell
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Publisher: SLU Forest Damage Centre, Swedish University of Agricultural Sciences
Layout: Cajsa Lithell
Cover illustration and illustrations in the report: Fredrik Saarkoppel

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Summary

The SLU Forest Damage centre develops knowledge and expertise at the scientific forefront to equip Swedish forests for current and future risks of damage.

This is achieved by stimulating the development of new knowledge in strategically prioritised subject areas and through analysis and synthesis of existing knowledge. The work is carried out in continuous dialogue with various actors inside and outside academia. The centre works across disciplinary boundaries.

The SLU Forest Damage Centre started in 2021 and has four pillars: analysis function, research school, research projects and monitoring. The centre shall contribute to the work of preventing and monitoring forest damage caused by storms, fires, drought, pests, pathogens and ungulate browsing.

The analyst function was established in May 2022. Our analysts work together with the external collaboration specialists at SLU and analyse national outbreak risks on an ongoing basis relying on existing data, compile knowledge, and carry out impact assessments, identifying knowledge gaps and contribute to the centre by providing knowledge support in the event of any kind of outbreak or incident.

Our research school is an important component both for knowledge development in the forest damage field and to supply competence within universities, research institutes, authorities, and forest companies. The research school is a collaboration with industry and authorities, and organizations outside SLU are invited to participate. Networks established within the research school are expected to facilitate future collaborations. In 2022, nine PhD student projects got funding and the first students have been enrolled.

In 2021, departments or units at SLU could apply for funding for research projects. During this initial phase, more than 70 projects were funded. In 2022, a project call funded 34 additional projects. Funded projects cover basic research as well as applied questions that are more directly connected to forest management measures. The centre also funded PhD student courses and scientists' exchange.

The monitoring activities at the SLU Forest Damage Centre reinforce and complement other ongoing monitoring projects and activities in Swedish forest ecosystems. In addition, our monitoring function supports methodology and model development in monitoring, including pre-studies to design set-ups for a given monitoring as well as pilot studies testing previously decided designs in the field.

The centre strives to be the natural first port of call for forest damage issues in Sweden in collaboration with multiple external stakeholders.

Sammanfattning

SLU Skogsskadecentrum utvecklar kunskap och forskning i framkant för att rusta svenska skogar för aktuella och framtida skadehot.

Vi stimulerar utvecklingen av ny kunskap inom strategiskt prioriterade ämnesområden och genom analys och syntes av befintlig kunskap. Arbetet bedrivs i kontinuerlig dialog med olika aktörer inom och utanför akademin. SLU Skogsskadecentrum arbetar över disciplingränserna.

Centret startade 2021 och har fyra delar; analysfunktion, forskarskolan, forskning och miljöövervakning. Centret bidrar i arbetet med att förebygga och övervaka skogsskador orsakade av stormar, bränder, torka, växtskadegörare, patogener och klövvilt.

Analysfunktionen etablerades i maj 2022. Våra analytiker arbetar tillsammans med de externa samverkanslektorerna på SLU. De analyserar löpande nationella utbrottsrisker utifrån befintlig data, sammanställer kunskap och genomför konsekvensanalyser, identifierar kunskapsluckor samt bidrar till centret genom att ge kunskapsstöd vid utbrott eller incidenter.

Vår forskarskola är en viktig komponent både för kunskapsutveckling inom skogsskadeområdet och för att tillföra kompetens inom universitet, forskningsinstitut, myndigheter och skogsföretag. Forskarskolan är ett samarbete med näringslivet och myndigheter. Organisationer utanför SLU är inbjudna att delta. Nätverk som etableras inom forskarskolan förväntas underlätta framtida samarbeten. År 2022, fick nio doktorandprojekt finansiering och de första doktoranderna har börjat.

År 2021 kunde institutioner eller enheter vid SLU ansöka om medel för forskningsprojekt. Under den här inledande fasen finansierades mer än 70 projekt. År 2022 finansierade en projektutlysning ytterligare 34 projekt. Finansierade projekt omfattar såväl grundforskning som tillämpade frågor som är mer direkt kopplade till skogsvårdsåtgärder. Centret finansierade också doktorandkurser och forskarutbyten.

Miljöanalysverksamheten vid SLU Skogsskadecentrum förstärker och kompletterar andra pågående miljöanalysprojekt och aktiviteter i svenska skogsekosystem. Dessutom stödjer vår miljöövervakningsfunktion metodik och modellutveckling inom övervakning, inklusive förstudier för att designa upplägg för miljöanalys och pilotstudier.

Centret strävar efter att vara den första instansen för skogsskadefrågor i Sverige i samarbete med ett stort antal externa aktörer.

PHOTO: IRYNA MATSIAKH

Starting a new centre

— Challenges and opportunities

In 2021, SLU got the assignment to start-up the SLU Forest Damage Centre. Since then, a lot has happened. The director and deputy directors of the centre started their work in September 2021, the administrative coordinator and a communicator followed in January 2022.

At that time, over 70 pilot projects at 15 different departments or units at SLU were already running – a challenge to keep track on these, but a great opportunity also to get things started!

In spring 2022, a new steering group started their work, and a reference group was appointed, both providing good opportunities for increasing the direct contact to our stakeholders.

In the centre, our four pillars have taken shape: the monitoring part was developed, eight analysts were assigned, 34 projects running between 2022 and 2024 got funding, and in the research school, nine PhD student projects were accepted, of which five are partly financed by external stakeholders. We are happy to get so many great opportunities to advance the knowledge on forest damage!

Establishing and keeping in contact with the many actors involved in forest damage questions, both within and outside SLU, has been another challenge. We have met this with excursions and workshops, project collaborations and participation in numerous events and activities on a national and international level. We see it as very positive that many are interested in our work, and are looking forward to more joint activities and a continuous dialogue on how to improve communication and collaboration.

In this report, you can read more about our vision and goal, people involved, the funded projects, monitoring activities, our research school and our analysis function.

What is next? Now that several pilot projects have finished, the first results will be summarized and reported. We will develop our communication strategy and will make sure that our contacts can reach us and get the information they need. More outreach activities such as seminars and excursions are waiting, and we will continue to strengthen our existing collaborations and to develop new ones. Do you want to take part in our activities or have ideas? We are looking forward to hearing from you!

Jonas Rönnberg,
Director of the SLU Forest Damage Centre

Förord på svenska

— Att starta ett nytt centrum - utmaningar och möjligheter

År 2021 fick SLU i uppdrag att starta SLU Skogsskadecentrum och sedan dess har mycket hänt. Centrumets föreståndare och två biträdande föreståndare började sitt arbete i september 2021, den administrativa koordinatorn och en kommunikatör följde i januari 2022.

Vid den tidpunkten pågick redan över 70 pilotprojekt vid 15 olika institutioner eller enheter vid SLU. Det har varit en utmaning att hålla reda på alltihop, men också en fantastisk möjlighet att få igång saker och ting!

Under våren 2022 inledde en ny styrgrupp sitt arbete och en referensgrupp utsågs, vilket gav goda möjligheter att öka direktkontakten med våra intressenter.

I centrumet har fyra pelare tagit form: miljöövervakningsdelen utvecklades, åtta analytiker utsågs, 34 projekt som löper mellan 2022 och 2024 fick finansiering, och i forskarskolan godkändes nio doktorandprojekt, varav fem delvis finansieras av externa intressenter. Det här har inneburit många fantastiska möjligheter att komma vidare med kunskap om skogsskador och vi är mycket glada över detta! Att etablera och hålla god kontakt med de många aktörer som är involverade i skogsskadefrågor, både inom och utanför SLU, har varit en annan utmaning.Vi har mött detta genom gemensamma exkursioner och workshops, projektsamarbeten och deltagande i många evenemang och aktiviteter på nationell och internationell nivå. Vi ser det som mycket positivt att många är intresserade av vårt arbete och ser fram emot fler gemensamma aktiviteter och en kontinuerlig dialog om hur vi kan förbättra kommunikationen och samarbetet.
Läs mer om vår vision och vårt mål, involverade personer, de finansierade projekten, miljöövervakningsaktiviteter, vår forskarskola och vår analysfunktion i denna rapport.

Vad är nästa steg? Nu när flera pilotprojekt har avslutats kommer de första resultaten att sammanfattas och rapporteras.Vi kommer att utveckla vår kommunikationsstrategi och se till att våra kontakter kan nå oss och få den information de behöver. Fler utåtriktade aktiviteter som seminarier och utflykter väntar, och vi kommer att fortsätta att stärka våra befintliga och utveckla nya samarbeten.Vill du delta i vår verksamhet eller har du idéer? Ta gärna kontakt!

Jonas Rönnberg, föreståndare för SLU Skogsskadecentrum

1. The organisation of the centre

The SLU Forest Damage Centre shall contribute to the work of preventing and monitoring forest damage caused by e.g. storms, fires, drought, pests, pathogens and ungulates. The centre shall work across disciplinary boundaries and in collaboration with the rest of society.

Activities and initiatives are carried out in consultation with external actors and the idea is that the centre will also coordinate and assist projects that are not directly funded by the centre. The centre strives to be a natural national entry point for forest damage issues without excluding old established contact routes.

The structure of the centre's organisation (Fig. 1) consists of two main parts, the day-to-day operations (light green parts in Fig.1), and the steering and advisory operations (dark green parts in Fig.1). The main activities include the research school, project and knowledge support, monitoring and the analysis function. The

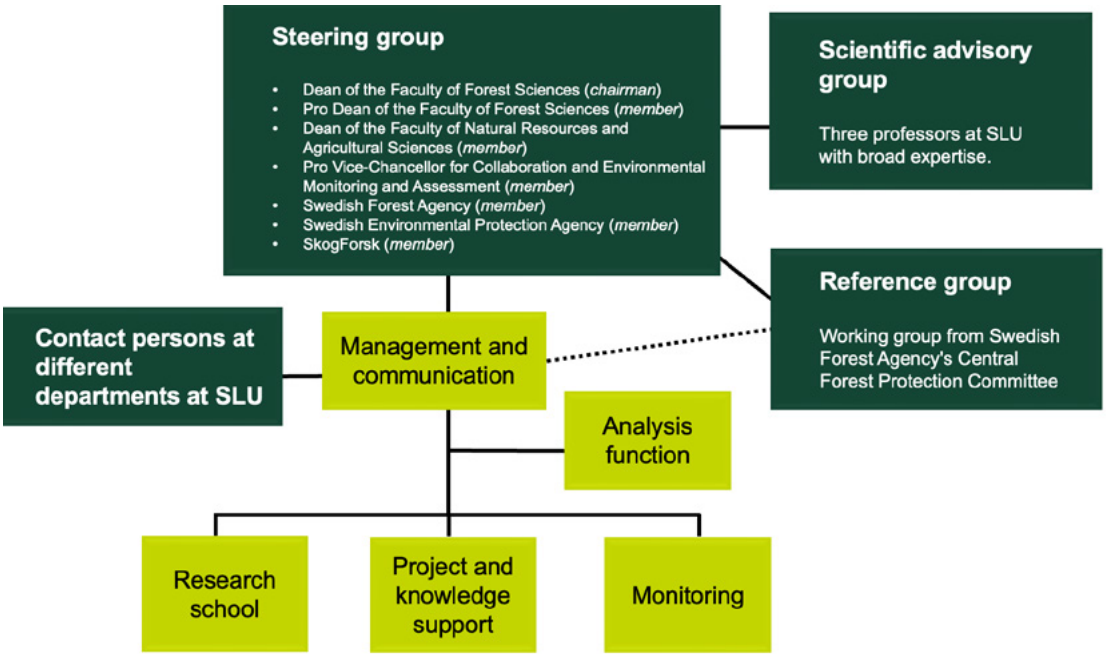

Figure 1: The organisation structure of the SLU Forest Damage Centre. The steering group is appointed by the vice-chancellor of SLU. Note that the Pro vice-chancellor for Collaboration and Environmental Monitoring and Assessment has left the post in autumn 2022; a new member of the steering group will be appointed by the vice-chancellor of SLU.

research school, monitoring as well as project and knowledge support feed into the analysis function. The SLU Forest Damage Centre can be seen as a platform for all staff at SLU that work with forest damage, i.e., even those that are not directly funded by the centre are included and invited to activities and can get support by, for example, spreading research news or other activities.

The management team of the centre has a meeting on a weekly basis, making decisions for day-to-day operations to run smoothly. Major funding decisions and strategic issues are the responsibility of the centre's steering committee, and the economist of the Forest Faculty at SLU handles the financial administration.

Contact persons at the different departments and units at SLU are a valuable source for input and one of our communication channels with the researchers at the different parts at SLU. The management team meets the contact persons about four times a year.

The task of the external reference group is, among other things, to evaluate and develop the societal benefits of the centre's activities and to assist in prioritising the activities in order to maximise their practical application. The director of the centre is taking part in the meetings of this group.

The evaluation committee supports the steering group and the management team with recommendations for the evaluation of project applications, PhD student project applications and monitor programs.

This structure has been adapted to ensure a smooth day-to-day management, transparency in decision making as well as advisory input from researchers at SLU (contact group) and from outside SLU (reference group).

The management team

The centres management team is responsible for day-to-day operations. Working time of each person is given in brackets. The Director and Deputy directors were appointed in autumn 2021, and the coordinator and communicator started in the beginning of 2022:

- Jonas Rönnberg, Director (50%)
- Wiebke Neumann Sivertsson, Deputy director, contact for monitoring (25%)
- Åke Olson, Deputy director, contact for the research school (25%)
- Katja Fedrowitz, Administrative coordinator (40% under 2022)
- Viktor Karlsson, Communicator (30%)

The reference group

Together with the Swedish Forest Agency, the centre has formalised an external reference group to the centre, which consists of the working group of the Swedish Forest Agency's Central Forest Protection Committee (CSK) and met for the first time in April 2022. The following organisations are involved in the working group as full members (substitute from the deviating organisation in brackets):

- Sveaskog
- Holmen Skog
- SCA Skog
- Swedish Plant Producers Association (SCA)
- Södra Skogsägarna (LRF Skogsägarna)
- Norra Skog (LRF Skogsägarna)
- Swedish Environmental Protection Agency
- Swedish Board of Agriculture
- SMHI (Swedish Meteorological and Hydrological Institute)
- MSB (Swedish Civil Contingencies Agency)

2. Visions and goals

The SLU Forest Damage Centre shall develop knowledge and expertise at the scientific forefront to equip Swedish forests for current and future risks of damage. We will achieve this by stimulating the development of new knowledge in strategically prioritised subject areas through analysis and synthesis of existing knowledge. This work is carried out in continuous dialogue with various actors inside and outside academia.

The SLU Forest Damage Centre has developed the following vision and goals under 2022, which still need to be decided on by the steering group under 2023:

2.1. Vision

The centre strives to be the natural first port of call for forest damage issues in Sweden.

2.2. Goals

- Generating knowledge and developing methodologies at the forefront of science
- To contribute to the highest scientific level of research on forest damage by SLU and others
- To create a solid national and international network for the exchange of knowledge and research related to boreal and temperate forests
- To produce and deliver data of the highest quality relevant to forest damage research issues

- To have a constructive collaboration with different actors in the forest sector in order to capture different needs for knowledge development and competence provision on forest damage
- To contribute with a relevant set of tools that safeguard a variety of management practices to address different types of forest damage with respect to biodiversity and other forest goods
- To produce forecasts and impact assessments that provide relevant information for forest management under a changing climate and forest damage risks

- To be a living platform that delivers relevant knowledge on different types of forest damage available to different end-users
- To be a communication channel that is responsive to questions and needs from the community on issues related to forest damage
- To be a trusted social actor in forest damage issues
- To produce monitoring data on forest damage for the needs of society and the forest sector over time

- To be the first national body to be addressed in the field
- To be a centre for creative thinking and dialogue between different actors
- To create an inclusive community for SLU and other researchers and environmental analysts working on forest damage issues
- To provide a relevant network between academia and other authorities, actors in the forest sector as well as the rest of society on issues related to forest damage

PHOTO: CAJSA LITHEL

3. Collaboration

Collaboration is a high priority for the SLU Forest Damage Centre. To take on the challenges of today and the future, it is important that we join forces and collaborate to include different competences and expertise to advance knowledge on forest damage.

In 2022, the interaction with the surrounding community has primarily concerned to work with the external reference group, where the centre has assisted in the organisation of the same together with the Swedish Forest Agency. The external reference group has on several occasions been asked about and assisted with views on the prioritisation and assessment of applications received. The steering group, with its external members, has met regularly during the first half of the year to decide on, among other things, the allocation of funds to applications received. Both the leadership group and the external reference group have also participated in a jointly organised field trip in May 2022. In addition, the centre's management has participated in different meetings, primarily with the Swedish Forest Agency, to disseminate information on the progress of the work and some initial results from started projects as well as to discuss and shape collaboration between interested parties.

PHOTO: ANNA LUNDMARK

Figure 2. Word cloud on projects' collaboration with authorities, interest groups and stakeholders for 2022. The Swedish Forest Agency is most frequent. 23 out of 34 projects that received funding in 2022 had collaboration with someone outside SLU.

The centre has bilateral collaboration with SkogForsk and Skogsstyrelsen, respectively, with regular meetings and exchanges.

Collaboration has also taken place in several communication activities together with the Swedish Forest Agency. This includes the Forest Damage Report (Skogsskaderapport), as well as presentations at several seminars and workshops, and co-organised field trips. For example, one of the analyst has participated in an excursion organised by the Ministry of Economic Affairs. The centre has also contributed to Södra's initiatives on climate-adapted forestry and the Glommen-Mjösen yearly forest symposium in Elverum, Norway. The centre also assists the Swedish Board of Agriculture and the ministry in its planning for the 2023 meeting of EU Heads of Plant Health (COPHS) in Sweden. The centre has also attended and disseminated information about its existence at one of Europe's largest agricultural fairs in Borgeby in collaboration with the Nordic Council of Ministers' Collaborating Body on Forestry (SNS – Nordic Forest Research) and Agricultural and Food Research (NKJ – Nordic Joint committee on Agriculture and food research).

Much of the centre's research is carried out in collaboration with external stakeholders, e.g. in direct collaboration, by making research materials available (e.g. facilities for field experiments), and through participation in surveys, but also through frequent discussions and exchanges of issues and results. More than half of the projects that were funded under 2022 have collaboration with someone outside SLU (Fig. 2).

SLU Risk assessment of plant pests

Some years before the SLU Forest Damage Centre was established, SLU got the task to build capacity for national pest risk assessments in response to the new EU-legislation. The specific aim was to provide pest risk assessments of quarantine pests for the Swedish Board of Agriculture, including pests that substitute a threat to forests. The SLU Forest Damage Centre was not supposed to overlap with this highly specialized ongoing risk assessment work. Therefore, the risk assessment unit is financed through the SLU Forest Damage Centre but has a separate primary stakeholder.

The SLU Risk assessment of plant pests unit performs independent analyses, providing support to the Swedish Board of Agriculture in their management efforts to counteract the damage of new organisms. Activities include pest risk assessments (PRA) of specific plant pests according to international standards as well as compilation of information and expert advice. The focus is on pests that would cause unacceptably high damage and whose introduction to Sweden may be prevented by phytosanitary measures.

In addition to risk assessment of specific pests, the unit also performs risk classifications and develops approaches to estimate the different values of plants and plant environments. The risk assessment includes pests in agriculture, forestry, horticulture, and natural areas but is limited to pests included in phytosanitary legislation and those who potentially could become regulated.

The analysts Johanna Boberg and Niklas Björklund at SLU Risk assessment of plant pests.
PHOTO: JENNY SVENNÅS-GILLNER, SLU

More information can be found here:
www.slu.se/risk-assessment

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4. Equality

In our view, equality comprises a sound distribution of thematic areas, cultural backgrounds and gender among the funded research project themes, their project leaders as well as in the different groups such as our management team, steering committee and analysts. At the same time, solid science is a high priority.

When it comes to language in our activities, reports and dissemination of information, there is the challenge to include both stakeholders in the Swedish forest sector as well as researchers with Swedish and international backgrounds. Meetings have both been in Swedish and English. We strive to have a high scientific level of research, and aim to translate the practical applications of this to Swedish. While our website is in both Swedish and English, we aim to translate documents to either Swedish or English when it feels appropriate regarding the content and main audience addressed.

4.1. Thematic areas of funded projects

In 2021, the thematic focus of the more than 70 funded projects was to a large extend on insects (22%), fungi (22%) and wildlife-related projects (15%) (Fig. 3 a). In 2022, most of the 34 funded projects were on fungi (35%), followed by insects (29%) and Heureka (24%) (Fig. 3 b). The nine PhD student projects that received funding in 2022 were in the thematic areas of fungi (56%) and wildlife (44%).

4.2. Gender distribution

We aim for an equal gender distribution considering competence and relevance in all components throughout the centre, including the management team, the analysts as well as funded projects.
For example, whereas the gender distribution of the projects funded in 2021 was uneven with 68% male project leaders, we succeeded with an equal gender distribution in 2022 (50:50). PhD project leaders for the nine projects that received funding in 2022 are to a large extend females (67%).

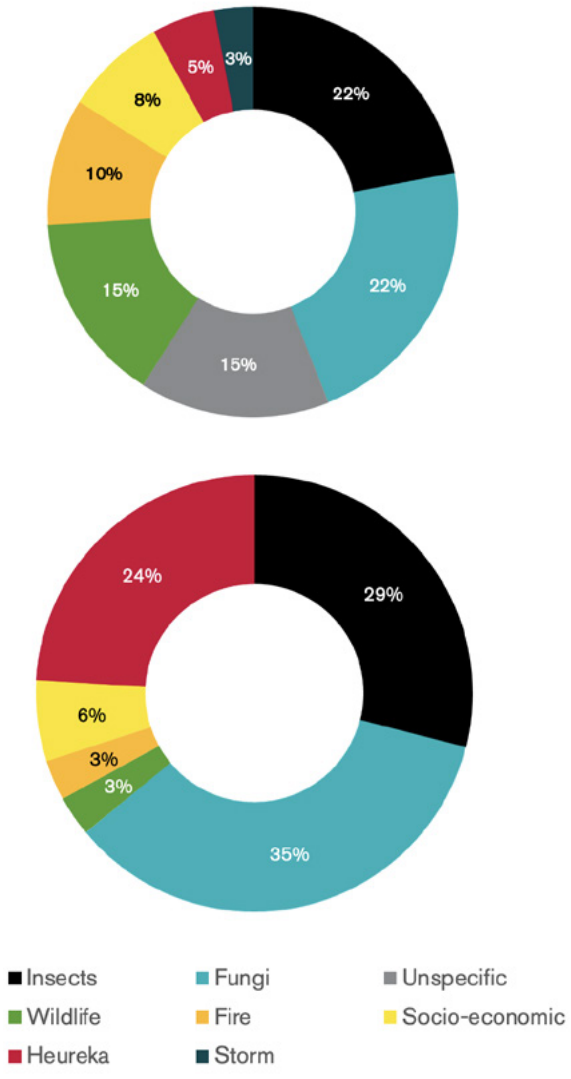

Figure 3. Distribution of funded projects in 2021 (a) and 2022 (b) into different thematic areas. Note that PhD student projects are not included.

5. Projects under 2021-2022

Project and knowledge support comprise one of the pillars of the SLU Forest Damage Centre. The main objectives for this are knowledge development to prevent forest damage and skills development related to forest damage and climate adaptation.

In 2021, departments or units at SLU could apply for both longer and more comprehensive projects as well as shorter, more detailed ones. During this initial phase, more than 70 projects were distributed among 15 departments or units (Appendix 1), including knowledge advancement, method development, pilot studies as well as syntheses. In 2022, a project call funded 34 additional projects, including research projects, monitoring pre-studies/development projects, support for PhD student courses or scientists' exchange.

Next to these calls, other strategic projects may be proposed by the centre's management team and decided by the steering group in the light of current needs within the SLU Forest Damage Centre. In addition to this, the centre funds several monitoring projects (see chapter 7).

Funded projects cover basic research as well as applied questions that are more directly connected to forest management measures. While most of the projects funded under 2022 are still ongoing, we present here a short overview on the covered areas as well as some preliminary findings from projects that received funding in 2021 and/or 2022. Note that a full list of projects is given in Appendix 1.

5.1. Insects

Insects like bark beetles (*Scolytinae*) can affect tree performance and survival, emphasizing the

Martin Schroeder has investigated spruce bark beetle outbreaks

Why do outbreaks of the spruce bark beetle start after warm and dry summers? Another question I had was which factors that are most important for collapse of outbreaks. My research shows that in the exceptionally warm and dry summer of 2018, the attack density of the spruce bark beetle in killed trees was low. This indicates that tree defences were compromised by the drought stress and that the reproductive success was unusually high.

With these data we know that the forest sector should be even more active in sanitation cuttings of attacked trees during summer to reduce the population increase and thus the damages in the following years. We also know that it is a good idea to reduce the use of spruce in regions with a history of summer droughts. In the future, I will continue to investigate why outbreaks of spruce bark beetle collapse.

need for understanding the outbreak dynamics of insect pest species across forest stands, particularly in those with high economic or biodiversity interests. For example, the spruce bark beetle (*Ips typographus*) has impacted more than 32 million m^3 of Swedish spruce forests since the very hot and dry summer in 2018 (https://www.skogsstyrelsen.se/nyhetslista/fem-miljoner-kubikmeter-dodades-av-granbarkborren-2022/). Ash is threatened by the Emerald Ash Borer (EAB), *Agrilus planipennis*, a species native to East Asia and spreading towards Europe from Russia. The EAB is present in Eastern Ukraine and is expanding its geographic area and number of infested trees. Research funded by the SLU Forest DamageCentre quantified e.g. the susceptibility to EAB.

Funded projects focused on competence development of practical skills (e.g. trapping methodology, or biology) and improved understanding on the effects of different silvicultural systems and forest complexity for interspecific interactions between bark beetles and their predators. Applied funded research with high relevance for forest management included method development to improve our detection opportunities of forest stands infested by bark beetles using remote sensing.

5.2. Fungi

Fungal pathogens affect forest ecosystems and forestry on several levels, from seed quality,

Malin Elfstrand develops new tools for seed orchard management

How do specific mother trees in Northern pine seed orchards contributes to the damages by *Cronartium pini* in pine plantations? This is a question that Malin Elfstrand wanted to answer.

– To estimate this we have screened a large number of seedlings from specific seed orchards growing in Norrbotten for damages by *C. pini.* Next, we genotyped both the progenies and the mother trees. Finally, we will determine if different mother trees in the orchard have progeny with different level of resistance, says Malin.

Malin and colleagues have recently received the genotype data from the mother trees in the seed orchard and their progeny in the forest. The next step is statistical analysis.

– We think the results will open possibilities for genetic thinning or selective harvests in seed orchards to improve resistance to fungal pests. Genetic thinning means that the trees that generates progenies with very high susceptibility is removed from the orchards.

The orchard owners could instead tailor the seedlings intended for planting in areas with a high risk of *C. pini* damages through selective harvest of seeds from the trees with the best potential for resistance.

In the future Malin, Jan Stenlid and other researchers will continue with this project in collaborations with the SLU Forest Damage Centre, Skogforsk and stakeholders. The SLU Forest Damage Centre has set aside more funds to make it possible to continue analysing the seed orchard's role in the problem with multi-damaged young pine forests.

seedlings in nurseries to individual trees and forest stands. To meet these challenges, funded projects in both years covered a range of topics, dealing with basic to applied questions, from identification to silvicultural measures in practice.

To follow the distribution and dynamics of fungal pathogens in the environment, monitoring is important to keep track of the distribution of possible threats. Several pilot/pre-studies have worked with method development and have evaluated different approaches, which is crucial to advance effectiveness in environmental monitoring of fungal pathogens in forests ecosystems. In addition to advanced understanding of the adequate physical collection of fungal spores, cost-effective methods for identifying fungal communities and taxa are relevant tools to detect the risk for fungal forest damage at a given place, including implication for targeting rare or low abundant pathogens. Threats by fungal pathogens can change over time and here the development of an early detection tool (such as using foliage, bark or wood) to screen for untargeted pathogens, including unknowns, is important.

Scots pine blister rust, caused by Cronartium pini.
PHOTO: BERIT SAMILS, SLU

Ash dieback (ADB), which is caused by an invasive pathogen, *Hymenoscyphus fraxineus,* is a serious threat to biodiversity as it can effectively kill forest stands of ash (*Fraxinus excelsior*). Today, we have access to improved molecular markers identifying ash individuals suffering from ash dieback, helping to monitor and study disease development. Research funded by the SLU Forest Damage Centre quantified the resistance of ash and the susceptibility to ADB as well as structural forest response to large die-offs in different stand compositions.

Resistance breeding is an important tool for long-term improving of forest health in Sweden. A review and workshop summarizing the current status in conifer resistance breeding are under production. This study will make it easier for stakeholders to decide on actions in the field of resistance breeding and to formulate short-term, mid-term and long-term goals in the research field.

The SLU Forest Damage Centre also supports method development and an investigation on how to organise a resistance screening centre for forest trees. This work is done in close collaboration with the Swedish Forest Agency and Skogforsk. A proof of concept for the screening methods has been shown and upscaling/implementation in large scale is under the way.

5.3. Wildlife

Browsing by different deer species affect both plant growth and survival at different development phases, in general with larger impact on seedlings, saplings and young trees than adult trees. High browsing pressure can hamper forest regeneration and can reduce the performance of economically valuable trees. Furthermore, browsing has important structuring effects on stand compositions and biodiversity. The relationship between browsing pressure and damage is, however, not necessarily linear, but relates to forage availability and inter-specific interactions. To balance the impact of browsing with goals in forestry, we therefore need an improved understanding on how levels of browsing damage correlate with stand index and tree volume produced across different settings of deer communities and forest stands. Hence, the

SLU Forest Damage Centre assigned resources to study these relationships in forest stands across a latitudinal gradient in Sweden, including browsing damage on Scots pine (*Pinus sylvestris*) as well as bark stripping of Norway spruce (*Picea abies*).

The SLU Forest Damage Centre has also launched a monitoring program (Balanserad klövviltstam – 'Ungulate populations in balance') to quantify the correlations between forage availability, forest stand characteristics, deer densities, browsing intensity and damage across different environmental settings (i.e. seven reference areas from Kronoberg to Norrbotten county), including the composition of ungulate communities.

Movement is a key feature of animals, and movement enables animals to relocate to favourable places and avoid unfavourable ones. Data on animal movement thus help to advance our understanding on how animals utilize the landscape and hence indirectly aid to monitor environmental conditions. Today, technical advances allow the collection of comprehensive data. Here, updated e-infrastructures are crucial to enable storage, handling and access of such data over time. Funding of the SLU Forest Damage Centre helped to improve the interface and services provided for users by the SLU e-infrastructure Wireless Remote Animal Monitoring (WRAM). Next, using moose movement data stored in WRAM, the centre funded a study on the resource utilization of different habitats by moose as a proxy for browsing risk in managed forest landscapes across Sweden.

5.4. Forest fires

Forest fires are natural disturbance regimes in boreal forests. However, modern forestry has successfully suppressed the occurrence and distribution of forest fires in managed forests during the past decades, affecting both forestry biomass production and biodiversity. Forecasts on climate change predict an increased risk for forest fire events in the future. For forestry, these predictions emphasize the need to better understand the effect of different forestry measures

We still have limited knowledge on the socio-economic consequences of forest damage.

following fire on future biomass production, as well as the need for a common database on fire features (e.g. starting point, weather conditions, forest characteristics) to develop fire risk indices in relation to forest conditions. In addition, forecasts on future climatic conditions predict higher ambient temperatures across Sweden, which can affect growth and performance of tree species and populations in managed forests.

During 2021-2022 the SLU Forest Damage Centre has supported some smaller and larger projects related to forest fires and drought. For example, one study focused on the effects of forest fires and forestry measures (e.g. ground preparation, logging) on the nutrition take-up and succession processes in spruce and pine stands, thereby improving our understanding on suitable management actions following forest fires. Moreover, funded research also included a study on drought tolerance and foliar fungal diversity in planted Scots pine stands. Assistant migration is a suggested measure to mitigate negative impacts of changed climatic conditions

Combating liverworts in forest nurseries

Liverworts infections are a growing problem in forest tree nurseries since most chemical treatments are no longer permitted. Daniel Gräns and colleagues wanted to investigate if spraying with low pH water could be a way to control liverworts infections. They also studied the effects on Norway spruce seedlings grown under these more acidic conditions.

– Water with a pH of 3 significantly reduced liverworts infections without negatively affecting seedling growth and vitality, says Daniel.

– Liverworts infections during nursery cultivation can reduce seedling vigor and cause mortality. Spraying with low pH water could possibly be used as an environmentally friendly way of controlling these problems. In the future, Daniel would like to perform a larger study at several different forest tree nurseries.

– At these new trials it would also be interesting to include different tree species. SLU researchers Anders Lindström, Elisabeth Wallin and Åke Olson also participated in the project. The staff at Lugnet's forest nursery was very helpful in handling the seedlings during the experiment.

on forestry. To improve our understanding on the effect of migration on growth in pine, the centre funded a study evaluating the performance of south-migrated pine in Southern Sweden. Next, to better understand the interaction among fuel, weather and fire spread, one project applied a modelling approach, including forests in Southern Sweden.

We still have limited knowledge on the socio-economic consequences of forest damage. This includes concerns by individual forest owners for forest fires as well as how scientific representation of damage like fires can affect policy management. To advance our knowledge on these aspects, the centre funded a survey and literature review. Sweden lacks a comprehensive database summarizing facts on wild and conservation (i.e. initiated for nature conservation purposes) forest fires. To evaluate the possibility for a common database, including a broad range of actors, the centre funded an initiative, including a workshop. There, all main actors involved in fire handling and management in Sweden were gathered to develop a first draft of the structure and information flow for a common e-infrastructure.

5.5. Heureka

Forest landscape models or forest decision support systems have become important tools to understand the effects of environmental change and decision of different management strategies on forest ecosystems over time. Today, plenty of such models exist, and they have been used frequently to this end. Heureka is a forest decision support system developed at SLU. Different packages consider different components in the simulation of the forest growth and biomass production over time, thereby allowing forest owners to trade-off different management

In Sweden, we have a large diversity of forest owners with privately owned forests dominating in the south and company-owned forests dominating in the north. PHOTO: KENNETH SCHULZE

interests. Abiotic and biotic impacts on forests are complex and often correlated. So far, however, packages including inter-correlation among different damage agents are limited and ask for comprehensive method development as well as data availability.

Funding efforts during 2021 have supported several studies focusing on the development of different modules as additions to Heureka, including studies on testing relationships among different damage agents. For example, one study focused on the analytical development of simulating stochastic events like storms, concerning storm intensity and frequency, as a component to become available within Heureka. Another study focused on the inter-correlation of risks for damage caused by wind, snow and spruce bark beetle in relation to different forestry measures in productive Swedish forests. Next, one study evaluated the trade-off among forests' storm sensitivity, forest age, timber production, net income and growth as well as forestry actions in neighbouring landscapes. Importantly, a literature review highlighted the current lack of forest decision tools considering risk and uncertainty globally, asking for better implementation of uncertainty in modelling systems like Heureka.

5.6. Socio-economic aspects of forest damage

Different forest damage come with different sets of socio-economic consequences and thus can generate different socio-economic implications for forestry, conservation and society. Across Sweden, we have a large diversity of forest owners with privately owned forests dominating in the south and company-owned forests dominating in the north. Owner categories differ in their capability to tackle consequences of forest damage and to mitigate risk for damage as well as perception of different damage types. Forest damage rarely affect one forest type at a time, whereas measures to handle damage and to mitigate future risk generally ask for effort on larger spatiotemporal scale, thereby involving a large set of forest owners. This emphasizes the urgent need to better understand the diversity across forest owners related to perception, perspectives, consequences as well as possibilities to tackle damage.

Following a study on forest damage perspective in relation to profession revealed three main perspectives on forest damage among forest pathologists, silviculturalists and ecologists,

with possible implications for practice as well as framing of forest damage impact strategic priorities (including mitigation and protection practical measures, funds allocations).

5.7. Other projects

Next to a set of clear thematic projects, the SLU Forest Damage Centre also funded diverse

Scandinavia's largest database infrastructure for wildlife research and management

The SLU e-infrastructure Wireless Remote Animal Monitoring (SLU-WRAM) is a national competence centre and e-infrastructure for biotelemetry sensor data from animals at SLU. SLU-WRAM has been active for 20 years and Holger Dettki has been the coordinator for SLU-WRAM since 2003.

– SLU-WRAM receives, manages, analyzes, saves, and visualizes sensor data from animals. The system currently contains data from both research and management projects all over Scandinavia, with around 292 million data rows from 37 different projects with more than 24 different species from and including 5 923 individual animals, says Holger.

Data is collected automatically in near-real time from 17 different sensor manufacturers in 33 different formats. About 70% consists of non-spatial sensor data such as heart rate or body temperature of animals, while 30% of the data set is 'classic' position data.

– This is Scandinavia's largest database infrastructure for wildlife research and management, and is central to SLU's internal and external collaboration on biodiversity and biologging, says Holger.

Moose and other ungulate species managed within SLU-WRAM from various research and management projects have direct links to forest damage.
– SLU-WRAM is operationally critical for SLU Forest Damage Centre's work with game grazing and biological diversity, and for the joint work with multi-damaged forest. Many projects rely on the WRAM infrastructure for automatic collection, storage and visualization of data for ongoing monitoring, analysis and prediction of habitat use, migration and forest damage by moose and other species.

– In future, the combination of data, both sensor data from SLU-WRAM and other global repositories, and environmental data from other sources like remote sensing, will provide research and environmental assessment with new and important possibilities and challenges, says Holger.

initiatives that consider forest damage. For example, the centre supported projects evaluating and developing the future process to improve the applicability of the e-infrastructure Skogsskada as a platform for both education on forest damage and monitoring of forest damage across different forest landscapes in Sweden. The centre also provided funding for a major framework project on 'multi-damaged forests' in 2021, where most work packages were completed in July 2022, but some will run until the mid of 2023.

Remote-sensing products are key tools to screen forests for damage across large spatiotemporal scales and will increasingly become so in future. For example, gap identification in canopy development using LiDAR data can help to pinpoint disturbances in forest succession. Remote sensing products can also help to map forest damage and risk, with input from the field observations as reference data and for verification. In Sweden, data of many different field inventories co-exist, but information are rarely coordinated. Here, one study evaluated the possibility for a common database as a way forward to advance the application of remote-sensing products in identifying and monitoring forest damage.

Soil conditions shape forest performance and vulnerability to threats and damage. To summarize the state-of-art as practical guidelines for forest owners, a study synthesized current knowledge, highlighting the importance of site adaption, improved soil physical properties (e.g., by increasing organic matter content), and in some cases liming and fertilization to reduce forest damage. Moreover, the recent SLU/SKS soil map can help identifying hotspots for both spruce bark beetle attack and for wild forest fires, thereby supporting decision-making within forestry.

Following rules to reduce the environmental impact due to pesticides, many chemicals commonly applied in forestry nurseries will be forbidden, which generates concerns on the implication for future handling of pathogens. To better understand these concerns, the centre funded a survey among forest tree nurseries highlighting the most severe risk for seedling production.

Bark beetles are trapped in the pheromone trap container. PHOTO: ANDREAS PALMÉN

To monitor young forest performance, a key activity is to estimate forest health, biomass production, development towards future forest stands as well as possible negative impacts of damage factors (e.g., pathogens, insects, herbivores). As such, young forest inventories produce data to support decision making for different goals on ecosystem services produced by forests, including data to feed into decision-support tools. So far, however, young forest inventories commonly focus on managed young forest stands and thus usually do not include non-commercial forests. Young forest inventories as parts of the permanent sites of the annual ordinary Swedish National Forest Inventory (NFI) fill this knowledge gap (logged 1998-2015). Today, different protocols and definitions to register damage exist among different actors involved in young forest inventories, possibly resulting in different conclusions, which may cause conflicts within nature resource management and asks for uniform definition of damage.

6. Analysing forest damage

6.1. The analysis function

The analysis function was established in May 2022. Two out of eight analysts started in January 2023, one of them was our analyst for socio-economic impact, Chandra Krishnamurthy, and the other one Johanna Lundström, working on risk and impact assessment using Heureka. The analysis function for damage caused by wind and snow is still empty. Our analysts work together with the external collaboration specialists (*samverkanslektorer*) at SLU and have the following assignment:

- To analyse national outbreak risks on an ongoing basis relying on existing data (e.g. monitoring data),
- to compile knowledge and to carry out impact assessments, identifying knowledge gaps, and
- to contribute to the centre by providing knowledge support in the event of any kind of outbreak/incident, thereby contributing to both external and internal communication.

During 2022, the centre's analytical function has started to take shape. The focus for several of the analysts has been to build up the concept for the respective analyst task, to map ongoing research and actors in the subject areas, to identify knowledge gaps, create work plans, and start networking inside and outside SLU. This work has for example included contacting different researchers, participating in seminars, workshops and conferences, taking part in courses and reading recent literature on the subject area, and most importantly, starting discussions with different experts and stakeholders on their interests and needs for the future.

Several analysts have participated in an excursion organised together with the central forest protection committee of the Swedish Forest Agency and in a workshop with participants from the external reference group. On these occasions, the focus, application and benefits of the activities have been discussed. Under the lead of Inka Bohlin and Narayanan Subramanian, the analyst group submitted a proposal for the session "New solutions for challenges in decision support for mitigating disturbances to increase forest health and resilience under climate change" to the IUFRO World Congress 2024 in autumn 2022.

Analysts at the SLU Forest Damage Centre, from left to right: Narayanan Subramanian, Inka Bohlin, Maartje Klapwijk, Fredrik Widemo, Audrius Menkis, Iryna Matsiakh, and Chandra Krishnamurthy (Johanna Lundström is missing). PHOTO: KATJA FEDROWITZ

Contact our analysts!

Do you want to contact any of our analysts? Welcome to get in touch!
www.slu.se/analysis-forest-damage

- Damage caused by insects: Maartje Klapwijk
- Damage caused by fungi, bacteria and viruses: Iryna Matsiakh and Audrius Menkis
- Damage caused by wildlife: Fredrik Widemo
- Damage caused by fire and drought: Inka Bohlin
- Damage caused by wind and snow: vacant
- Socio-economic impact: Chandra Krishnamurthy
- Risk and impact assessments with Heureka: Narayanan Subramanian and Johanna Lundström

6.2. Damage caused by insects

Attacks by the spruce bark beetle on standing healthy spruce forests have increased sharply in recent years in Sweden. Major damage has caused strong concern about further subsequent insect problems in forestry. Maartje Klapwijk is working as an analyst at the SLU Forest Damage Centre.

Tunnels made by the European spruce bark beetle.
PHOTO: VIKTOR WRANGE

Her speciality is forest damage caused by insects. During 2022, Maartje has been working on a spruce bark beetle susceptibility index (see figure 4 for the parameters)

– The susceptibility index can be used to assess susceptibility to spruce bark beetle attack at stand level. We have reviewed the literature for those biotic and abiotic stand characteristics that we know affects bark beetle attack and included that when we created the index, says Maartje.

– During the outbreak 2022, data has been collected using forest harvesters that have rather detailed information on the number of harvested trees, the tree species and for spruce whether the tree was attacked. In collaboration with Professor Anneli Ågren at SLU, we have matched this information with a detailed soil moisture map.

– Currently, we are working on understanding the tree conditions that underlay at the start of an outbreak and, in addition, if these conditions change during an expansion of the outbreak.

International collaboration of insect invasions

Maartje Klapwijk is part of an international collaboration on biogeographical patterns in insect species invasion, comparing species invasion and host association in EU and Eastern USA.

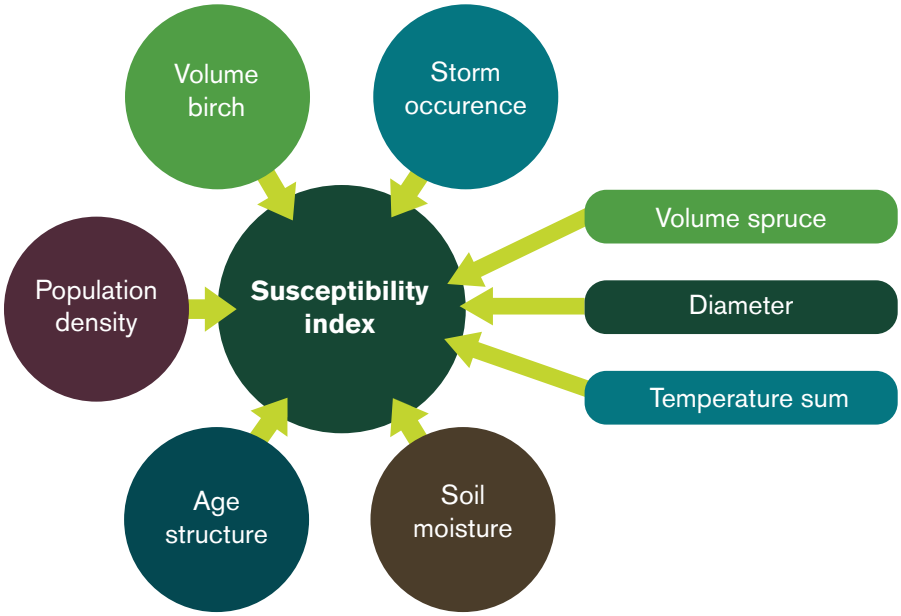

Figure 4. The parameters contributing to the susceptibility index.

– We want to understand the relationship between tree species distribution patterns and the likelihood of herbivorous insect species invasions. With the changing climate, the risk of non-native species establishing in Sweden is increased. Therefore, understanding what families or species of trees are more likely to be new host plants for non-native species is important for the decision on what tree species to plant for future forestry, says Maartje.

The project that Maartje is leading is relating the number of non-native species associated with a certain tree family or species to the number of native herbivorous insect associated and the geographic distribution range of the tree species.

Courses and networking

Maartje has been involved in developing a course for the SLU Forest Damage Centre Research School.

– This course is the first course in a series called Forest damage – incidence and causation. The whole course is aiming to introduce PhD students to forest damage in general. The entomology part will be partly diagnostics together with a focus on species biology and ecology.

During 2022, Maartje has been widening her research network by connecting researchers in forest entomology with researchers in biological conservation and by taking part in a new research project.

– I have also started a discussion with stakeholders about the research needs resulting from the spruce bark beetle outbreak and understanding the existing knowledge gaps that need filling. And I have facilitated a collaboration between SLU and the Swedish Environmental Protection Agency to provide knowledge about spruce bark beetle in nature reserves.

The largest gathering of forest researchers and practitioners

Maartje is one of the leaders for the division for forest health within the International Union of Forest Research Organisations (IUFRO) as well as a member of the conference scientific committee for the IUFRO world congress 2024.

– The World Congress is taking place in Stockholm on the 23-29 June 2024. The congress is the largest gathering of forest researchers and practitioners globally. During the congress, cutting

edge research will be presented. For the first time in the recent history of IUFRO there will be a keynote address on forest health by Professor Andrew Liebhold from the USDA Forest Service. Throughout the congress, many sessions will focus on all aspects of forest health from remote sensing to interactions between different damage agents. There will also be a session organised by the analysts of the SLU Forest Damage Centre.

6.3. Damage caused by fungi, bacteria and viruses

Iryna Matsiakh and Audrius Menkis share the task as analysts for damage caused by fungi, bacteria and viruses at the centre. They have started working on a review of forest pathogenic *Phytophthora* species present in Sweden. *Phytophthora* is a genus of plant-damaging oomycetes (water molds), whose member species are capable of causing enormous economic losses on crops worldwide, as well as environmental damage in natural ecosystems. Iryna and Audrius analysed available data, identified knowledge gaps and produced information that can be used for creating disease risk maps.

Currently, there are more than 80 described species of *Phytophthora* worldwide, and most of them are plant pathogens.

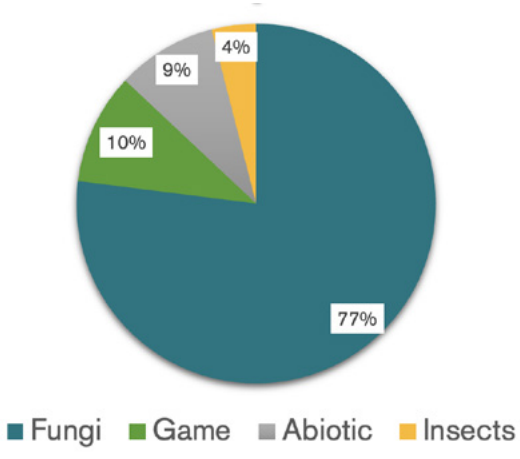

Figure 5. Agents of damage detected during disease diagnostics in 2022.

– *Phytophthora*-damage was noted on European beech (*Fagus sylvatica*) trees in recreational forests and parks, and on horse chestnut (*Aesculus hippocastanum*) trees in urban settings around Skåne since 2010-2011, says Iryna.

– During 2016-2017, excessive *Phytophthora*-damage research was conducted across Skåne to evaluate distribution, risk and threat that new invasive *Phytophthora* species may pose to Swedish forests, cities and landscapes. Several species were found in soil indicating the presence of *Phytophthora* species as damaging agents, which may lead to future problems for Christmas tree plantations, says Iryna.

– Besides, due to expected increase in production and planting of deciduous trees such as birch, different *Phytophthora* species can be especially important both in forest nurseries and after seedling outplanting, says Audrius.

Phytopthora damage. PHOTO: IRYNA MATSIAKH

A list of detected *Phytophthora* species

The information was used to compile a list of detected *Phytophthora* species in Sweden: species status, infected tree host, symptoms, first report in Sweden, distribution in Sweden, infected tree species in Sweden, geographical range and references.

– This information will help us to create the risk maps and will be used for writing a review publication and for identifying needed research activities, says Iryna.

During the year, the analysts have also provided diagnostics and advisory services.

– We made a few diagnostics for private forest owners, plus one for Alnarp park. This capacity was not fully utilised, and perhaps we need to advertise to the stakeholders that this service exists in southern Sweden, says Iryna.

During 2022, disease diagnostics and advisory services at SLU in Uppsala were provided on several occasions to the forestry companies Svenska Skogsplantor AB, Södra Skogsplantor, Stora Enso Skog AB, Holmen Skog AB, SCA Skog AB and Sydplantor AB.

– In addition, the Swedish Forest Agency, the Forestry Research Institute of Sweden - Skogforsk, Svartsjö Trädkonsult AB and private persons approached us regarding diseases in forests and on urban trees, says Audrius.

Altogether during 2022, there were 68 such service requests received. Some results of these diagnostics for 2022 are shown in figures 5 and 6.

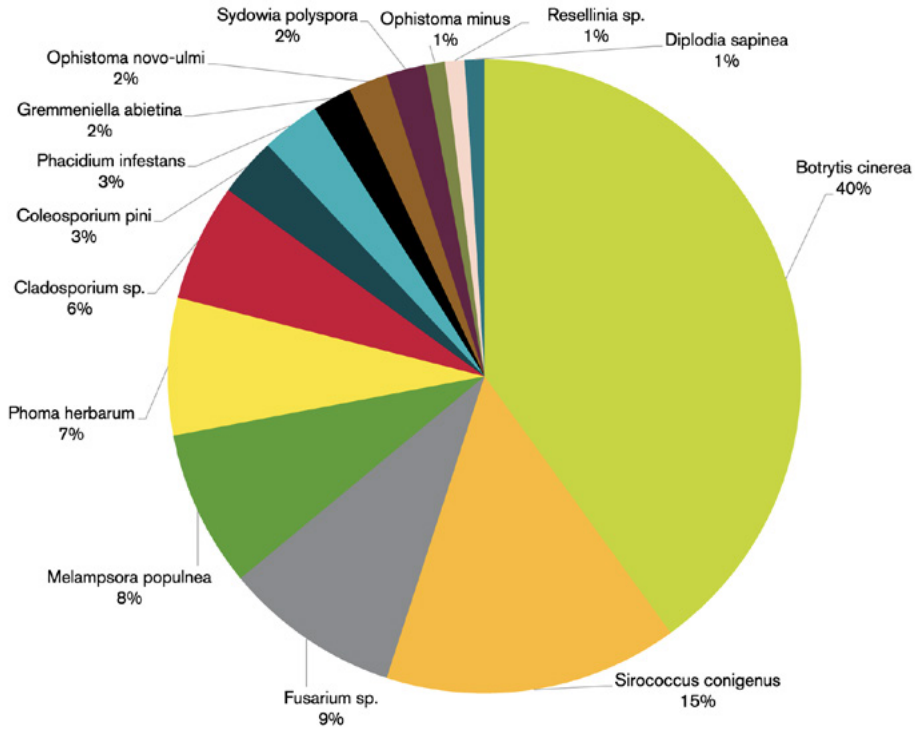

Figure 6. Fungal species detected during disease diagnostics in 2022. Other important diseases such as pine blister rust (caused by Cronartium sp.) root-rot (caused by e.g. Heterobasidion spp.) or ash dieback (caused by Hymenoscyphus fraxineus) were diagnosed by other researchers working specifically with these diseases and are not represented in this diagram.

The visited clear-cut site in Hällefors area where the seedling dieback were evaluated. PHOTOS: AUDRIUS MENKIS

On request by Stora Enso Skog AB, four replanted clearcuts were visited in the Hällefors area and three clearcuts in the Alfta area, and possible reasons for a seedling decline were evaluated.

– Together with Svenska Skogsplantor AB, we visited the seed orchards Larslund and Gotthardsberg. There, we looked at incidences of the pathogenic fungus *Diplodia sapinea*. We also organised online meetings with representatives from Svenska Skogsplantor AB and Stora Enso Skog AB, during which tree seedling diseases in forest nurseries were presented and possible solutions of disease management were discussed, says Audrius.

6.4. Damage caused by fire and drought

There are many researchers working with fire and drought at SLU's different campuses. They research plant physiology, genetics, ecology, management, planning, risk, inventory, history and socio-economic issues to mention a few examples.

Inka Bohlin is the analyst responsible for forest damage caused fire and drought at the SLU Forest Damage Centre.

– As an analyst, I am especially interested in working with questions related to risk assessment of forest fires and drought and how to consider these in forest management. This can include developing more accurate knowledge of risk for fire and drought in a forest landscape or including risk information and risk analysis as part of forest management planning. In addition, I help the centre with questions related to remote sensing, says Inka.

Cooperation between research and rescue services

In November, Inka participated in the 9th International conference on Forest fire research in Portugal, which is held every 4th year and collects the experts on forest fires all around the world. The presentations included different topics on wildfire management and safety, risk reduction, assessment, and adaption, decision support systems and tool and fire and wildland urban interface.

– Many fire fighters attended the conference and better co-operation between research and rescue services was especially highlighted for improved knowledge transfer and implementation to practice. For me, the conference was very valuable for getting to know the current topics worldwide and the organizations and people working with forest fires. I got new ideas for my future work and a possibility to create new contacts worldwide, says Inka.

Inka Bohlin is tha analyst responsible for damage caused by fire and drought. PHOTO: PRIVATE.

During 2022, Inka participated in two analysis tasks; data analysing of the photo-interpreted fuel classification project by Anders Granström at SLU and planning the test of fire detection sensors by Skogstekniska kluster, which will both continue in 2023. She was also asked to give a lecture on remote analysis of forest damage in the undergraduate course "Diagnosis, prevention and management of biotic forest damage" at SLU.

– I am also working as a remote sensing researcher and as an associate coordinator in the environmental monitoring program "Forest" with focus on remote sensing and mapping. This creates connections and knowledge transfer between researchers and stakeholders working with remote sensing and forest damage, which benefits the SLU Forest Damage Centre, says Inka.

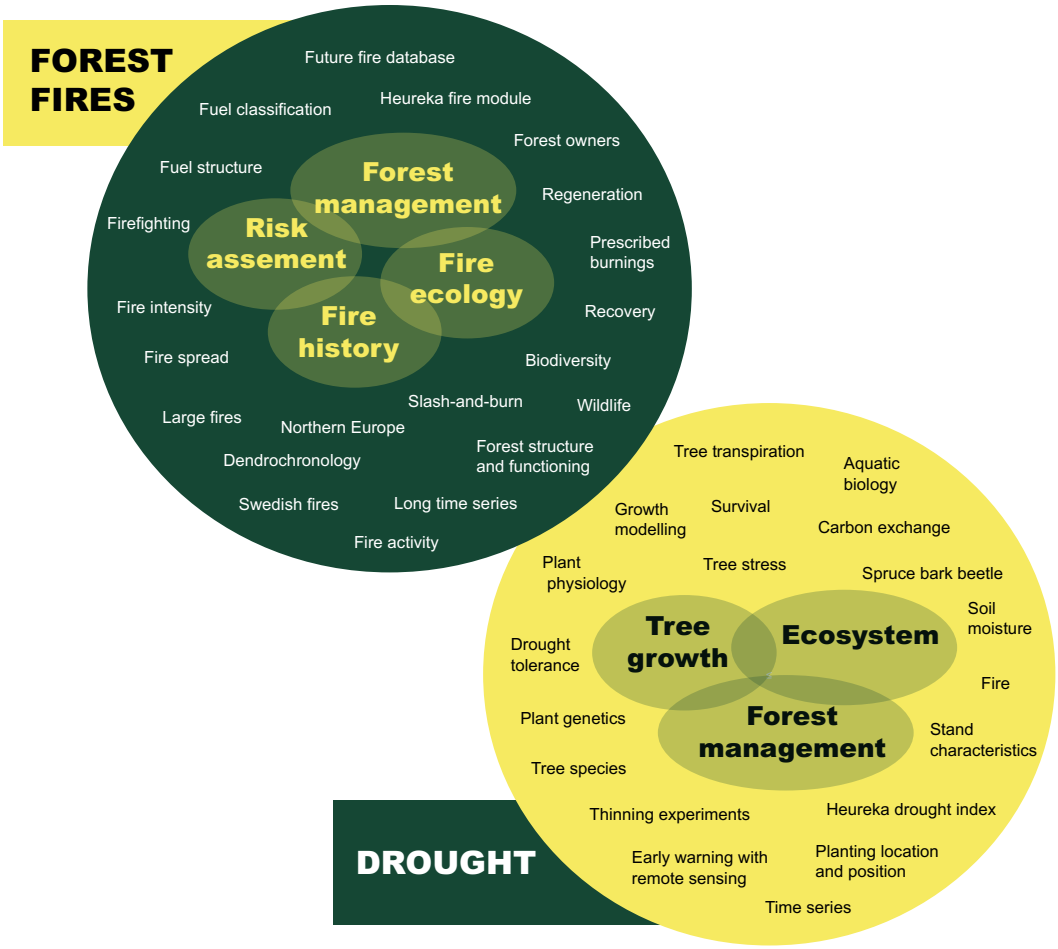

Figure 7. Research areas at SLU within forest fire and drought.

6.5. Risk and impact assessments with Heureka

Narayanan Subramanian started working as an analyst at the Centre in 2022 and in 2023 Johanna Lundström will join as an analyst in this area.

Narayanan has, together with Jorge Aldea, a previous postdoc at SLU, worked with the randomization of storm events in a Heureka project. Currently the storms in a Heureka model are deterministically implemented. The past storm events are implemented with the same intensity and frequency as in their historic pattern.

– The user can randomize the storm events for its intensity and/or frequency by increasing and decreasing the intensity and/or frequency by a specific percentage. Currently the storm randomizer is not a part of Heureka software but we are working on the possibility to integrate it into the Heureka model, says Narayanan.

In the HEUREKA project, a project to include risk assessments of storm events is ongoing.

Narayanan has been in discussion with the startup company Skogrkaupa regarding the possibility of evaluating their simulation tool for predicting the carbon sequestration, growing stock under various management scenarios.

– I have also been in discussion with the Swedish forest agency with regards to a simulation study on future impacts of browsing damage in Värmland.

6.6. Wildlife damage

The moose population grew rapidly in the 1960s and 1970s, peaking in the early 1980s. Since then, the population has been reduced by increased hunting. Despite this, damage levels have not fallen correspondingly. Moose population densities have long been monitored by bag statistics, and since the 1990s, also using observations collected by hunters while hunting moose. The Wildlife Damage Area of the SLU Forest Damage Centre is based on the current research results and needs for knowledge and monitoring methods. Fredrik Widemo is the analyst responsible for damage caused by wildlife.

ÄBIN is short for ÄlgBetesINventeringen, which means "inventory of moose damage". The focus of wildlife damage to forests has long been on damage to pine trees caused by moose. Since 2000, damage has been inventoried within the management by ÄBIN through the Swedish Forest Agency. The method was originally developed for pine-dominated stands and its application has changed over the years. The method has been revised over the years; since 2015, randomly selected young stands are inventoried using the same methodology at the level of ÄFOs (moose management areas) across Sweden, regardless of stand composition.

– During 2022, the centre has been in close dialogue with the Swedish Forest Agency on the design of ÄBIN as an inventory method, as well as the need for additional inventory information, for example on how browsing pressure affects recruitment and tree species composition. These discussions will continue in 2023, says Fredrik.

Several PhD projects have been initiated within the framework of the centre, aiming, among other things, to investigate how today's damage targets measured with ÄBIN relate to future stand composition and how browsing damage will limit forest management and yields in the future.

Damage has increased in all regions

Calculations of damage trends since the introduction of the uniform ÄBIN inventory in 2015 show that, as of the 2022 measurement, damage has now decreased in all regions.

– Since 2022, the SLU Forest Damage Centre has been running a project to develop a new module within Heureka to calculate how current browsing pressure may affect future stands. It will be available for use in various Forest Damage Centre projects as well as within the management once it has been validated, says Fredrik.

Measuring forage availability and forage utilisation

In 2022, the environmental monitoring programme "Ungulate populations in balance" was launched with reference areas to measure forage availability and forage utilisation of ungulate communities with different compositions, which will initially run from 2022-2024.

– The aim is to study the ecological relationships across a latitudinal gradient, to develop predictions of the occurrence of damage and how this may change due to land use change and climate change. The programme is mainly based on monitoring areas where historical data from different periods are available through previous projects, and most areas have also been monitored as pilot projects within the SLU Forest Damage Centre, says Fredrik.

In addition, in 2022, the programme "Balanced strains of cloven-hoofed game" received support from the Swedish Environmental Protection Agency to acquire and deploy 100 game cameras

Fredrik Widemo is the analyst responsible for damage caused by wildlife. PHOTO: PRIVATE

in some of the reference areas to monitor game distributions during the summer months, whereas most of the current analyses are based on faecal pellet counts that only show where game has been during the winter.

– In some of the reference areas there are also moose with GPS collars today, as well as historical data on moose movements. Limited data are also available for other ungulates. The analysis of moose movement patterns in the landscape is one of the PhD projects carried out in the framework of the SLU Forest Damage Centre's graduate school, says Fredrik.

The results so far show that there are large differences in the total energy requirements of ungulate communities. The reference area with the highest total energy requirements for ungulates had the lowest moose density.

– At the same time, forage availability was lowest across all types of forage, while forage utilization and proportion of damaged pine stems were highest. This again illustrates the importance of examining the effects of the ungulate community as a whole, says Fredrik.

PHOTO: CAJSA LITHELL

7. Monitoring

The monitoring activities at the SLU Forest Damage Centre reinforce and complement other ongoing monitoring projects and activities in Swedish forest ecosystems. In addition, our monitoring function support methodology and model development in monitoring, including pre-studies to design set-ups for a given monitoring and pilot studies testing previously decided designs in the field.

Hence, during the starting up phase of the centre, funding has been allocated to the following:

A. Pre-study: Molecular monitoring of fungal pests
B. Pre-study: Monitoring of priority biotic pests - feasibility study and proposals for long-term monitoring
C. Pilot study: Monitoring of the relationship among deer abundance, browsing pressure, and forage availability ('Balanced ungulate populations', Balanserad klövvilstam')
D. Pilot study: Sample-based plant and young forest inventory within the National Forest Inventory (NFI)
E. Monitoring of spruce bark beetle (*Ips typographus*) population on established plots
F. Coordinator of the National Targeted Damage Survey (NRS).

During 2022, the steering group approved the conversion of activities C-E into long-term activities funded by the SLU Forest Damage Centre. The two pre-studies (A, B) were finalized in December 2022. During 2021 and 2022, the centre also co-funded the Wireless Remote Animal Monitoring (WRAM), a database structure handling and storing sensor data of among others large herbivores across Sweden. In addition to these wider efforts, a number of shorter (e.g., one-year) studies have been funded focusing on methodology development, data assurance and making existing data available, such as possibilities for a common database on forest fires gathering data from various Swedish actors, data sets from earlier monitoring on spruce bark beetle as well as National Targeted Damage Surveys.

Next to the decided long-term activities, the centre has allocated major funding to advance and update the technical elements and to improve the content of the public reporting system on forest damage (Skogsskada: www.slu.se/skogsskada)' during 2023/2024.

This work will be done in close collaboration with the SLU Swedish Species Information Centre and the Swedish Forest Agency. During spring 2023, the design and set-up of pilot studies as suggested by the two pre-studies (A, B) will be discussed in the leading group. In collaboration with the SLU Swedish Species Information Centre and Data Management, a workshop will take place to educate leaders for long-term activities on data storage and transfer of monitoring data into suitable SLU supported database structures.

A pre-study of molecular monitoring of fungal pests will be performed. PHOTO: CAJSA LITHELL

7.1. Collaboration in monitoring

The various decided environmental monitoring activities funded in 2021 have been developed in collaboration with stakeholders (e.g., the Swedish Forest Agency, the Swedish Board of Agriculture and researchers at various institutions). Pilot studies that converted into long-term activities and have been funded so far (i.e., C, D) have been assessed for societal relevance by the external reference group as well as the scientific quality by the scientific advisory group, both of which were only appointed in 2022. Even though, the decided monitoring activities have a long duration, they will be continuously evaluated and may be re-evaluated in several respects (we suggest a four year cycle between evaluations synchronised with the governmental decision on the centre's continued core funding, with a first evaluation taking place in 2024).

Monitoring at the SLU Forest Damage Centre

During fall 2021, the leadership group developed an evaluation process structuring the decision process for funding of long-term monitoring activities within the Forest Damage Centre. The steering group approved the suggested decision process in winter 2021/2022. The approved decision process assesses both the quality standards and needs of society of the anchoring monitoring, making use of the evaluation committee and the external reference group, respectively.

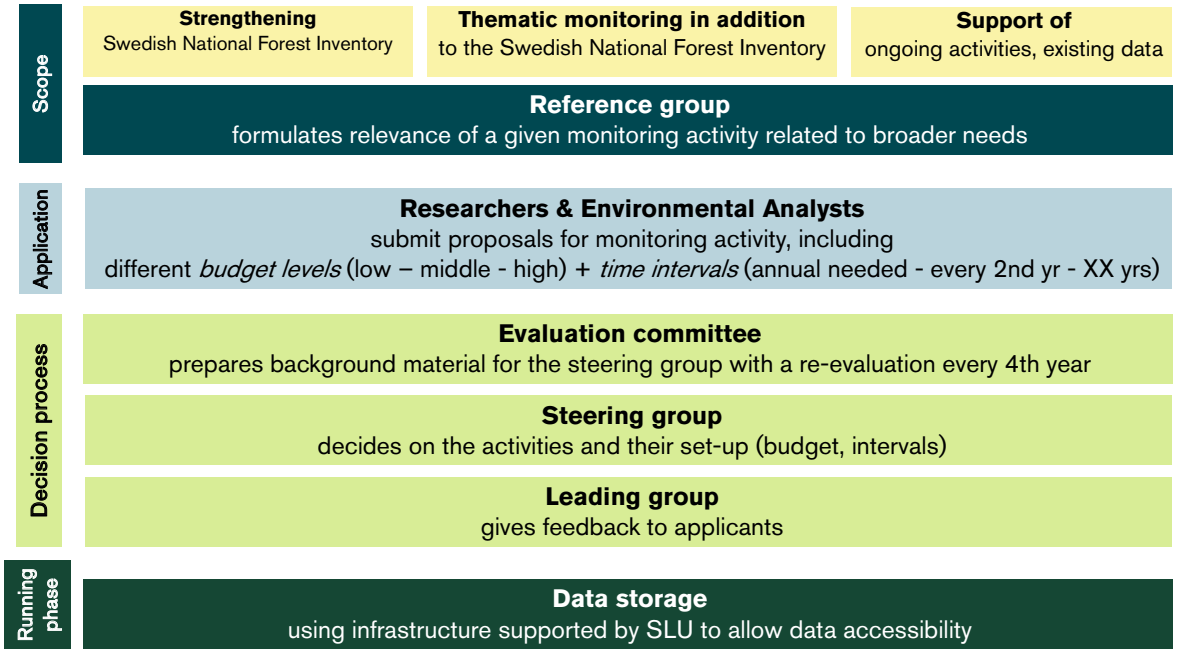

Figure 9. Decision process for monitoring activities within the SLU Forest Damage Centre

8. Research school

The research school at the SLU Forest Damage Centre is an important component both for knowledge development in the forest damage field and for the supply of competence within universities, research institutes, authorities, and forest companies.

The SLU Forest Damage Centre's research school will train researchers with broad expertise on risk and consequences of forest damage. The graduate school is open to all PhD students at SLU who are interested, regardless of whether one's education is financed by the SLU Forest Damage Centre or not. The research school is an industry/authority research school, where organizations outside SLU are invited to participate. Networks established within the research school are also expected to facilitate future collaborations.

In 2021, the SLU Forest Damage Centre began to establish a research school in collaboration with actors with an interest in forest damage. Researchers and stakeholders met and discussed research areas, problems, and areas of interest in forest damage at an excursion in the autumn of 2021. Subsequently, organisations were given the opportunity to submit expressions of interest to co-fund PhD students and, if so, in which area. At the same time, the SLU Forest Damage Centre organised a call for proposals internally at SLU in the early spring of 2022, where researchers could submit proposals for PhD projects that could match requested subject areas as well as other important research questions relevant to managing forest damage.

After internal (review panel) and external (reference group) evaluation of the proposals, the steering committee prioritized the PhD projects to be co-funded by SLU Forest Damage Centre. Nine students were funded, out of which six have external stakeholders participating in their projects (table 1). In autumn 2022, a second call came out for financing of additional doctoral projects. The results of this call will come in 2023.

8.1. Future research school activities

The research school plans to organize an annual meeting for all PhD students, supervisors and contact persons at companies and other organisations. At the meeting, lectures on forest damage will be offered and plans for the research school's work will be discussed. In addition, SLU's research school in forest damage will arrange annual excursions where various affected areas are visited, and where forest damage is discussed in the field.

The research school will also offer three postgraduate courses in the field of forest damage 1) Forest damage - incidence and causation, 2) Forest damage - inventory and monitoring, 3) Forest damage consequences and management. The courses are open to all PhD students. The first course will run in May 2023.

Contact the research school

Information on courses and where to apply:
www.slu.se/fdc-researchshool

To register at the graduate school, contact:
Åke Olson, Deputy Director,
ake.olson@slu.se

Table 1. PhD student projects financed by the research school in 2022.

Title	Department at SLU	Main supervisor
Identification of risk factors behind the current outbreaks of *Cronartium pini* in northern Sweden *	Forest Mycology and Plant Pathology	Berit Samils
Infection biology and management of emerging diseases in tree seedling production *	Forest Mycology and Plant Pathology	Audrius Menkis
Can continuous cover forestry reduce the risk of damage by forest pests and browsing ungulates?	Department of Wildlife, Fish and Environmental Studies	Anne-Maarit Hekkala
Plants for planting –Plant health in production storage and planting *	Forest Mycology and Plant Pathology	Åke Olson
Rädda Asken: breeding for resistance in European ash *	Southern Swedish Forest Research Centre	Michelle Cleary
Samband mellan klövviltets täthet, deras foder och betesskador i produktionsskogen *	Southern Swedish Forest Research Centre	Annika Felton
Future Yields-impacts of browsing on stand structure, forest growth and revenue in forestry	Department of Wildlife, Fish and Environmental Studies	Fredrik Widemo
Landscape utilization of large and long-lived herbivore in multifunctional forestland	Department of Wildlife, Fish and Environmental Studies	Wiebke Neumann Sivertsson
A new model to predict and breed for spring frost damage	Forest Genetics and Plant Physiology	Rosario García Gil

*Projects marked with * are co-financed by an external partner.*

9. Communication

The SLU Forest Damage Centre communicate with a website as well as news updates via email and news articles. We have dialogues with different actors, arrange workshops, study visits, excursions, courses and seminars as well as publish research reports.

Since 2022, the centre have a website (www.slu.se/skogsskadecentrum or www.slu.se/forestdamagecentre) on which events and news connected to forest damage research at SLU are published and where the contact details of the management team and the analysts can be found. Also, several of the analysts were presented in short news articles on the website. The website is still under development.

Information spreading is currently done via our reference group, the SLU Plant Protection Network, the steering group, the contact persons at the different departments, and via the internal newsletter from the SLU Forest Faculty. In future, we may have a separate email list with people interested in news from the SLU Forest Damage Centre.

We also have been present in many other media, such as the magazine Skogen and the national news television, SVT.

A freelance writer is currently working on several popular science papers, compiling existing knowledge of forest damage.

In 2021 and 2022, we have had dialogues with different actors during workshops, seminars and excursions. For example, two field trips were organised, one together with SCA and the other with the Swedish Forest Agency, with participants from both SLU and external stakeholders (authorities and companies). The first one was organised in October 2021 in SCA's forests in Jämtland where pine forest affected by Scot's pine blister rust and storm damage areas were visited. Öster malma in Södermanland was also visited in May 2022. Game grazing and the ravages of the spruce bark beetle as well as root rot on pine were discussed there. The centre has also facilitated a common input from SLU to the yearly Forest Damage Report (Skogsskaderapport) from the Swedish Forest Agency.

A picture visualising the main thematic areas that the SLU Forest Damage Centre is covering has been developed to be used for presentations related to the SLU Forest Damage Centre (see the front page of this report). As an example, the picture has been printed on a roll-up that was shown at Borgeby Fältdagar and at the Swedish National Plant Protection Conference in Uppsala in 2022.

We are still developing our communication strategy where we aim to create a regular information flow between the centre, SLU's forest damage researchers and our stakeholders.

Jonas Rönnberg talks about the SLU Forest Damage Centre at the Swedish National Plant Protection Conference. PHOTO: CAJSA LITHELL

10. Economic review

		Budget 2022	Outcome 2022
INCOME/AVAILABLE FUNDS			
	Transferred from last year/capital	9 391	9 391
	Annual budget allocation	28 000	28 000
Total available		**37 391**	**37 391**
MANAGEMENT			
	Secretariat, salaries	2 712	2 130
	Operations (web page, excursion, communication)	500	306
	Kick-off/ yearly meetings	300	0
Management total		**3 512**	**2 436**
ANALYSIS FUNCTION			
	Salaries	1788	1536
	Drift (annual meeting, support for excursions)	1500	253
Analysis function, total		**3 288**	**1 789**
RESEARCH SCHOOL			
	Salaries, PhD students	2 550	443
	Drift	500	69
Research school, total		**3 050**	**512**
PROJECTS & KNOWLEDGE SUPPORT			
	Projects	12 500	4 613
	Exchanges	1 000	287
Projects, total		**13 500**	**4 900**
ENVIRONMENTAL MONITORING			
Monitoring, total		**4 650**	**3 100**
TOTAL COSTS		**28 000**	**12 737**
RESULT		0	15 263
Outstanding capital transferred to 2023		9 391	24 653
Comments to the results 2022			
The large positive result is primarily due to that many activities did not start during 2022 but was decided and contracted.			
The large capital will therefore be utilized during the coming two-three years.			
Capital		9 391	24 653
Annual budget		28 000	22 374
Available in total		37 391	37 391
Result		9 391	12 737

Appendix 1: Projects supported by the SLU Forest Damage Centre

Projects financed by the SLU Forest Damage Centre during 2021

Note that some of these projects consisted of several sub-projects.

Title	Leader	Department
En generell mobil inrapporteringsmodul för systemet 'Skogsskada'	Holger Dettki	SLU Swedish Species Information Centre
Preparation for long term contribution to the Forest Damage Centre at Ecology	Maartje Klapwijk & Adriana Puentes	Department of Ecology
Utvärdering av systemet SkogsSkada och alternativa ystemlösningar.	Mats Jonsell	Department of Ecology
Expertstöd och övervakningsinsatser kopplat till pågående barkborreutbrott	Martin Schroeder	Department of Ecology
Långsiktig övervakning av granbarkborre	Mats Jonsell	Department of Ecology
Övervakning av granbarkborrens förökningsframgång i dödade träd	Martin Schroeder	Department of Ecology
Förekomst av fiender till granbarkborre i skyddade områden och produktionsskog	Simon Kärvemo	Department of Ecology
Vilka bestånd och ståndorter är mest utsatta för angrepp av granbarkborre	Maartje Klapwijk	Department of Ecology
Effekten av bekämpningsmetoden Sök och Plock på ranbarkborrens fiender	Martin Schroeder	Department of Ecology
Övervakning av prioriterade biotiska skadegörare – förstudie och förslag till långsiktig övervakning / Monitoring of prioritized biotic pests and pathogens –pilot study with a proposal for long-term monitoring	Maartje Klapwijk	Department of Ecology
Pilot study-trapping of black bark beetle (*Hylastes*) from fresh and one-year old clearcuttings	Charlotta Erefur & Kristina Wallertz	Unit for Field-based Forest Research
Spormonitoring vid de skogliga försöksparkerna	Charlotta Erefur	Unit for Field-based Forest Research
Pest management and forest biodiversity in selection systems	Charlotta Erefur & Adam Ekholm	Unit for Field-based Forest Research
Förstudie och analys av kunskapsläget angående skaderisker i olika skogsskötselsystem och tillhörande ekonomiska jämförelser	Charlotta Erefur	Unit for Field-based Forest Research
Ecotypic variation of tradeoffs between growth and defense: The role of lignin and associated metabolites in Scots pine and Norway spruce	M Rosario García-Gil	Department of Forest Genetics and Plant Physiology
Soil properties related to forest damage	Johan Stendahl	Department of Soil and Environment
Review and workshop on conifer resistance breeding	Malin Elfstrand & Berit Samils	Department of Forest Mycology and Plant Pathology
Collection of ash dieback-tolerant ash material for research and restoration	Rimvis Vasaitis, Audrius Menkis & Jan Stenlid	Department of Forest Mycology and Plant Pathology

Forest regeneration: nursery diseases	Åke Olson & Audrius Menkis	Department of Forest Mycology and Plant Pathology
"Stress biology" – Interactions between *Diplodia sapinea* and *Melampsora pinitorqua* on pine	Jan Stenlid	Department of Forest Mycology and Plant Pathology
Comparative genomics analysis of pathogenicity traits in Russulales	Mikael Brandström Durling	Department of Forest Mycology and Plant Pathology
Assembly of knowledge and tentative recommendations on conservation of high nature conservation values after damages	Anders Dahlberg	Department of Forest Mycology and Plant Pathology
Detection and monitoring of airborne fungal spores	Åke Olson, Audrius Menkis & Karl Lundén	Department of Forest Mycology and Plant Pathology
Review on forest pests and diseases from the east	Rimvis Vasaitis	Department of Forest Mycology and Plant Pathology
Multiskadad skog	Jan Stenlid	Department of Forest Mycology and Plant Pathology
Molekylär övervakning av svampskadegörare – förstudie	Åke Olson	Department of Forest Mycology and Plant Pathology
Systemanalys av drivningsarbete vid bekämpning av granbarkborre	Björn Edlund & Thomas Norfjell	Department of Forest Biomaterials and Technology
Effect of climate change on the potential importance of invasive blue stain fungi on wood quality; a preliminary study	Geoffrey Daniel	Department of Forest Biomaterials and Technology
Fotografering och tolkning av Riksskogstaxeringens provytor för klassning av bränsletyper	Anders Granström	Department of Forest Ecology and Management
Studying the Dynamics of Forest Canopy Gaps a Part of an Early-Warning System of imminent Forest Damage	Arne Pommerening	Department of Forest Ecology and Management
Betydelsen av brandhårdhet och ett varmare klimat på föryngring av tall och gran	Marie-Charlotte Nilsson Hegethorn	Department of Forest Ecology and Management
Pilotprojekt - Utveckling av riskkartor för skogsskador / Development of risk maps for forest damage	Anneli Ågren	Department of Forest Ecology and Management
En samlad svensk databas för vegetationsbränder	Anders Granström	Department of Forest Ecology and Management
Economic effects of moose damage	Peichen Gong	Department of Forest Economics
Value chain of timber prodcuts	Anders Roos	Department of Forest Economics
Perceptions of forest damage	Francisco Aguilar	Department of Forest Economics
Governance of forest damage	Camilla Widmark	Department of Forest Economics
Inventering av forskningsbehov för att kontrollera skadegörare i skogsplantskolor/ Survey regarding research needs within the field of plant protection at forest tree nurseries	Daniel Gräns	School for Forest Management
Kontroll av levermossa och rotpatogener i skogsplantskolor / Control of liverworts and root pathogens in forest tree nurseries	Daniel Gräns	School for Forest Management
Scientific discourse on wildfires and perceptions of risk among Swedish forest owners and managers	Sara Holmgren	Department of Urban and Rural Development
Sammanfatta kunskapsläget runt vilka skaderisker klimatförändringar för med sig på lång sikt	Jeanette Eggers	Department of Forest Resource Management

Hantering av risker i olika beslutsstödsystem i andra länder	Karin Öhman	Department of Forest Resource Management
Testa och validera stormriskindex i PlanVis	Karin Öhman	Department of Forest Resource Management
Overarching project to show the potential of mapping forest damage from remote sensing data	Eva Lindberg	Department of Forest Resource Management
Detection of spruce bark beetle infestations from remote sensing data	Huo Langning	Department of Forest Resource Management
Skattning och kartläggning av stormskador med radarfjärranalys / Estimating and mapping of storm damaged forest using radar remote sensing data	Johan Fransson	Department of Forest Resource Management
Riksskogstaxeringen/NRS; ungskogsinventering metodtester	Sören Wulff	Department of Forest Resource Management
Kan Riksskogstaxeringens ÄBIN-ytor utgöra en resurs för studier av hur skogsstillståndet utvecklas i förhållande till graden av älgbetesskador?	Jonas Fridman	Department of Forest Resource Management
Modellera olika typer av skogsskador simultant	Magnus Ekström	Department of Forest Resource Management
Forest Damage Database - a possibility for remote sensing applications	Henrik Persson & Eva Lindberg	Department of Forest Resource Management
BarkBin: första steget i utvecklingen av ett nationellt övervakningsprogram för viltskada på bark i produktionsskogen	Annika Felton	Southern Swedish Forest Research Centre
Long-term monitoring of multispecies ungulate communities in reference areas	Annika Felton	Southern Swedish Forest Research Centre
SKOGSBRAND: forskning, övervakning och integrering i ett planerat Forest Damage Centre (FDC) för att bilda ett SLU-nätverk, genomföra workshops, och att identifiera behov och prioriterade insatsområden	Igor Drobyshev	Southern Swedish Forest Research Centre
Monitoring forest responses and recovery to catastrophic pathogen-induced tree loss - a resurvey of elm and ash forest stands after 30 years	Jörg Brunet & Adam Felton	Southern Swedish Forest Research Centre
Spread of larger fires in Sweden: what are the forest stand properties, which predict fire spread? (FireSpread-H)	Igor Drobyshev	Southern Swedish Forest Research Centre
Nanopore MinION sequencing as a new tool for rapid detection and identification of tree pathogens.	Michelle Cleary	Southern Swedish Forest Research Centre
Forest damage in the perception of scientists – problem conceptualization, driving mechanisms and practical implications for the Swedish forestry	Vilis Brukas	Southern Swedish Forest Research Centre
Enabling Heureka model to generate random storm events	Narayanan Subramanian & Jorge Aldea	Southern Swedish Forest Research Centre
Electronic root rot detection adjusted for Scots pine	Iryna Matsiakh	Southern Swedish Forest Research Centre
Mixed-forest resilience for insect pests and biodiversity under climate change: effects of semiochemical and landscape diversity.	Mattias Larsson	Department of Plant Protection Biology
Geografisk skala för samförvaltning älg-skog	Fredrik Widemo	Department of Wildlife, Fish, and Environmental Studies
Betydelsen av fodertillgång och betestryck i fält och buskskikt för skador	Fredrik Widemo	Department of Wildlife, Fish, and Environmental Studies
Betydelsen av vinter –och sommarbete för tillväxt av skog	Fredrik Widemo	Department of Wildlife, Fish, and Environmental Studies

Älgbetets påverkan på tillväxt och virkeskvalitet hos tall/ Långtidseffekter av betestryck på biomassa och virkeskvalitet	Tomas Nordfjell, Fredrik Widemo & Göran Ericsson	Department of Wildlife, Fish, and Environmental Studies
Validering av måltal inom samförvaltningen av klövvilt-tall	Fredrik Widemo	Department of Wildlife, Fish, and Environmental Studies
Rörelse och risk för betesskada från klövvilt / Predicting browsing risk by ungulates	Wiebke Neumann	Department of Wildlife, Fish, and Environmental Studies
Finansieringsbehov SLU-WRAM inom Skogsskadecentrum 2021	Holger Dettki	Department of Wildlife, Fish, and Environmental Studies
Pilot- och utvecklingsprojekt Balanserade klövviltstammar - övervakning och analys av klövviltets inverkan på svenska skogsekosystem	Fredrik Widemo & Göran Ericsson	Department of Wildlife, Fish, and Environmental Studies

Projects financed by the SLU Forest Damage Centre during 2022

Title	Leader	Department	Type
Considering Uncertainty in Forest Management Planning	Irene de Pellegrin Llorente	Department of Forest Resource Management	Course
Forest Change detection with Google Earth Engine	Rubén Valbuena	Department of Forest Resource Management	Course
Making data from the long term monitoring of spruce bark beetle available - a work of restructuring data-files	Mats Jonsell	Department of Ecology	Data structuring
Expert support to authorities, forest organisations and private forest owners about the spruce bark beetle	Martin Schroeder	Department of Ecology	Expert Support
Pilot study – trapping of black bark beetle (Hylastes)	Kristina Wallertz	Unit for Field-based Forest Research	Monitoring
Molecular quantification of airborne fungal spores collected in spore traps	Åke Olson	Department of Forest Mycology and Plant Pathology	Monitoring
Ungskogsinventering i SLU Riksskogstaxeringen	Cornelia Roberge	Department of Forest Resource Management	Monitoring
Inventory of fungal infections in the forest landascape surrounding spore traps	Ulf Johansson	Unit for Field-based Forest Research	Monitoring
Reproductive success of the spruce barkl beetle during different outbreak phases	Martin Schroeder	Department of Ecology	Research
There is always two sides of the coin? Bark beetle outbreaks and promotion of biodiversity	Simon Kärvemo	Department of Ecology	Research
Ungulate grazing, habitat structure, and predation pressure on pest insects	Michelle Nordkvist	Department of Ecology	Research
Predicting susceptibility for attack by Spruce bark beetle – validation of the susceptibility index	Maartje Klapwijk	Department of Ecology	Research
Non-industrial private forest owners' knowledge and views on management of multi-damaged forest	Thomas Kronholm	Department of Forest Biomaterials and Technology	Research
Effect of climate change on the potential importance of invasive blue stain fungi on wood quality	Geoffrey Daniel	Department of Forest Biomaterials and Technology	Research
Assessing drought tolerance and foliar fungal diversity in Scots pine planted stands	Rosario García Gil	Department of Forest Genetics and Plant Physiology	Research
Fast sexual/asexual form identification and population diversity investigation of *Cronartium pini*	Ke Zhang	Department of Forest Mycology and Plant Pathology	Research
Breeding-without-breeding a new tool in seed orchard management for improved *C. pini* resistance?	Malin Elfstrand	Department of Forest Mycology and Plant Pathology	Research

Resistance screening method for Scots pine blister rust	Berit Samils	Department of Forest Mycology and Plant Pathology	Research
Developing and implementing a drought index in Heureka	Jeanette Eggers	Department of Forest Resource Management	Research
Forest damage sampling simulator	Anton Grafström	Department of Forest Resource Management	Research
MoMoMo: Moose Damages in Heureka – Models, Monte Carlo simulation and Robust Optimization	Lars Sängstuvall	Department of Forest Resource Management	Research
Joint modelling of forest damages using presence-absence data	Cornelia Roberge	Department of Forest Resource Management	Research
"Flying tree healthy analyser": drone-based hyperspectral imagery for early detection of bark beetle infestation	Langning Huo	Department of Forest Resource Management	Research
Coping with forest damages: evidence and adaptation strategies	Francisco X Aguilar	Department of Forest Economics	Research
Development of alternative measures to control liverworts infections during seedling cultivation and storage	Daniel Gräns	School for Forest Management	Research
Implementing Monte Carlo based random storm generator in Heureka Decision Support System	Narayanan Subramanian	Southern Swedish Forest Research Centre	Research
Modelling of forest fuel and weather effects on fire spread in Southern Sweden (FF-SPREAD)	Igor Drobyshev	Southern Swedish Forest Research Centre	Research
Testing seed treatments to reduce damage by pathogenic fungi in conifer seeds	Iva Franic	Southern Swedish Forest Research Centre	Research
Electronic root rot detection	Iryna Matsiakh	Southern Swedish Forest Research Centre	Research
Safeguarding Scots pine using nanopore sequencing for the detection and diagnosis of pathogens	Patrick Sherwood	Southern Swedish Forest Research Centre	Research
Browsing repellents for protecting Scots pine in northern Sweden	Urban Nilsson	Southern Swedish Forest Research Centre	Research
Pest management and forest biodiversity in the selection system	Therese Löfroth (Adam Ekholm)	Department of Wildlife, Fish, and Environmental Studies	Research
Breaking new grounds in Forest pathology	Nils Högberg	Department of Forest Mycology and Plant Pathology	Symposium
Research visit to FGI for "Flying tree healthy analyzer": dronebased hyperspectral imagery for early detection of bark beetle infestations	Langning Huo	Department of Forest Resource Management	Research visit

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