Digital technologies, risk management solutions and tools for mitigating forest disturbances support building a sustainable society

Impact story: MULTIRISK

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1. Impact objectives

Our overarching goal of MULTIRISK was to provide advanced digital technologies and risk management solutions and tools for mitigating forest disturbances caused by European spruce bark beetles and windstorms. We aimed at to develop: 1) advanced geospatial technologies for detecting and monitoring forest disturbances, and 2) efficient solutions and tools for sustainable risk management at different spatial and temporal scales. We also aimed at to demonstrate, co-develop, and communicate efficient digital technologies, risk management solutions and tools with key stakeholders in the society. Based on this we aimed at to enhance their utilization potential in practical forestry and the science-based risk management under a changing operative environment, which supports climate change adaptation and mitigation.

2. Actions

In WP1 we developed geospatial technologies for detecting and monitoring forest disturbances. For the goal, we have collected field reference data and multitemporal datasets using drones, multispectral helicopter LiDAR and optical satellites. Data have been used in developing detection methods and establishing means of monitoring, and finding answers for feasibility and performance aspects.

In WP2 we developed various solutions and tools for sustainable risk management in forestry at different scales.

In WP3 we demonstrated, co-developed, and communicated efficient digital technologies, risk management solutions and tools with key stakeholders, to enhance their utilization potential in practical forestry.

Results and outcomes of the project have been presented to domestic and international academia and expert audiences.

Currently we are seeking for further funding opportunities to continue specifically the SBB early attack signature on multispectral lidar and drone data. In addition to ongoing projects, bridging funding is provided by FGI and UNITE flagship, as well as SCANFOREST research infrastructure in terms of computational methods and analysis research.

3. Success and challenges

Pre-emergence detection of bark beetle infestations represents a significant gap in the current literature and operational monitoring practices. Efficient autonomous drone-based sensing approaches have strong potential to enable earlier intervention and improved outbreak management.

In WP1 we succeeded in developing 1) Multispectral LiDAR and drone based technologies for detecting dead and degraded trees, 2) Deep learning based system for estimating tree mortality based on aerial and high-resolution satellite imagery, 3) Digital systems for detecting, monitoring and impact assessing of European spruce bark beetle infestation, 4) Drone imaging, multispectral LiDAR and inside canopy techniques for early detection of SBB infestation.

A novel deep learning based method was developed for detecting standing dead trees and estimating tree mortality from aerial images (Junttila et al. 2024). The method was applied over an area of 117 000 ha in South-Eastern Finland to measure changes in standing dead tree cover and volume during 2017-2023. The study revealed a tenfold increase in the volume of standing deadwood during the study period, and the proportion of damaged Norway spruce dominated forest stands increased. The developed method is currently in operational use at KOKO Forest Oy and has been used to produce information for forest health and the amount of standing dead trees across an area of 4 million hectares in Finland for the Forest Centre. The study also gained widespread attention in the media and has been covered by The Guardian and Helsingin Sanomat.

See:

https://www.hs.fi/talous/art-2000010363797.html

https://www.hs.fi/tiede/art-2000009067094.html

https://www.hs.fi/mielipide/art-2000009512188.html

https://www.theguardian.com/environment/2024/oct/15/finland-emissions-target-forests-peatlands-sinks-absorbing-carbon-aoe

Another deep learning-based method was developed to detect standing dead trees from very high-resolution satellite imagery (below 1 m) and used to measure annual changes in standing deadwood across eight study areas in Southern Finland (Ajithkumar et al., manuscript under review). The developed method showed high accuracy in detecting standing dead trees with F1-scores up to 0.83. We have also developed a satellite image time series based method for evaluating the timing of tree death when dead tree locations are known (Nowak et al., manuscript under review). The method is based on PlanetScope satellite imagery and a change detection to provide annual data on mortality timing for individual and clusters of dead trees.

Scalable drone-based remote sensing techniques were developed for bark beetle damage detection and forest health monitoring (Turkulainen et al., 2025). In collaboration with Kelluu Oy, hydrogen-powered airships were deployed as long-endurance aerial platforms to acquire multispectral imagery, enabling wide-area data collection through extended (up to 12-hour) beyond visual line-of-sight (BVLOS) operations and overcoming spatial and temporal limitations of conventional UAV systems. Advanced deep learning approaches based on transfer learning and domain generalization were developed to reduce reliance on extensive annotated training datasets. Deep learning models trained using datasets from specific study areas could be transferred and applied to new geographic regions with differing environmental conditions, significantly improving model scalability and operational applicability for large-area forest health monitoring.

As a result of multispectral laser scanning flights, we now have a unique multitemporal dataset to explore for signature and features of SBB infestation on canopy degradation in both geometric 3D and spectral domains. This provides us a basis for fostering the technology and processes to a more wide exploitation, e.g. as part of the national forest inventory and monitoring efforts. We found that we can improve individual tree segmentation significantly by using multispectral data. Further, we could improve tree species classification to be able to focus analysis on only spruces, and also, detection of dead trees was found to be very reliable from the multispectral lidar data. By analysing the multispectral features from the reference spruces in 2023, we found out that the spectral signal of canopy/needle degradation was emphasized as difference to the initial stage at the early summer 7.6.2023. It was shown that the development of the canopy discoloring could be detected by all the combinations of reflectance differences in seven (7) weeks from the initial data.

Pre-emergence detection of bark beetle infestations represents a significant gap in the current literature and operational monitoring practices. Efficient autonomous drone-based sensing approaches have strong potential to enable earlier intervention and improved outbreak management. Hyperspectral feature analysis demonstrated that green shoulder–based vegetation indices provided the highest sensitivity to early physiological stress induced by infestation, enabling detection of pre-emergence infestation signals approximately 3–5 weeks after the initial attack, prior to visually observable crown discoloration, thereby supporting early-stage forest health assessment (Huo et al.,2023). Furthermore, even earlier detection may be achieved using close-range sensing approaches based on autonomous drones operating within forest stands. RGB imagery acquired by inside-forest flying drones enabled identification of bark beetle–damaged trees immediately after attack through the detection of trunk-level indicators, including entry holes, resin flow, and frass accumulation.

In WP2 the project has evaluated at different spatial and temporal scales the factors affecting the risks of European spruce bark beetle and wind damage in forests, and possible solutions that can be used to improve risk management in forestry at different scales. It has also developed a GIS-based wind damage risk and multi-risk (wind damage and European spruce bark beetle) tools (prototypes), which utilize open-source data. These tools can be used to evaluate the risks of spruce bark beetle and wind disturbances at the forest landscape level under different stand and management configurations and environmental conditions. However, their implementation into practical forestry is challenging, at least in the short term, due to the restrictions of information systems of different actors. The dissemination of project findings have increased among different stakeholders awareness of the increasing risks of European spruce bark beetle and wind damage in forests, and their possible cascading effects, as well as of the need for considering such risks in forest management.

In WP3, several seminars and meetings were organized with key partners, such as Metsä Group, Metsähallitus, Tapio and the Finnish Forest Centre. Forest damage has increased in recent years, and European spruce bark beetle in particular is a threat to forestry. Therefore, there has been great interest in our project and its results. The project also supported the activities of the National Land Survey of Finland, especially the planning of the national laser scanning programme.

The project involved national collaboration with the UNITE flagship, https://uniteflagship.fi/ and Natural Resource Finland (LUKE, https://www.luke.fi/en). The project also enabled several collaboration meetings and seminars with our international partners: Linnaeus University https://lnu.se/en/, SLU https://www.slu.se/en/ and Czech University of Life Sciences Prague https://www.czu.cz/en.

The project has also supported education in forest science by offering doctoral dissertation opportunities to several new researchers, and through dissemination of findings in MSc. degree courses.

The biggest challenge is the continued funding for the research: the project results are significant, and their potential for utilization is clear both in Finland and elsewhere in the world. However, the funding situation has become tighter and therefore the challenge is to secure the continued funding for the research and, to the transfer of research knowledge into practice.

4. Impact mechanism

The new remote sensing and forest risk management knowledge and solutions developed in the project can be put into practice through partner collaborations, e.g. Metsäkeskus is partnering in current projects, where we transfer research methods into practical implementations.

Our research has shown that by harvesting storm-damaged trees and trees affected by European spruce bark beetle in a timely manner and by considering the risks of wind and European spruce bark beetle damage in forests in the planning of harvesting (time and place), the risks of damage caused by them can be reduced in forestry.

Awareness of the possibilities of new remote sensing, GIS and decision support methods has increased during the project, and therefore readiness for their implementation also exists. The research made possible by the project has promoted and can continue to promote entrepreneurship and innovation in the sector both in Finland and elsewhere in Europe.

5. Medium- and long-term impact and systemic effects

In the short and medium term, awareness of the possibilities and limitations of new methods is key.

Forestry practices are improved by capability to monitor canopy changes to detect problems in water circulation, pests and nutrients, to name a few. These are crucial in and could enhance digital forest information services for resource management and forest value chains. It is predicted that future forest services use predominantly digital data based planning and management to mitigate climate related risks in forest resources by fostering data driven awareness of the impact of SBB and wind risks in various forest composite scenarios and management practices.

In the longer term, the results of the project and the solutions produced, as well as GIS-based risk management tools, can significantly promote the consideration of various forest damage risks and the uncertainties caused by them in decision-making in forestry both in Finland and elsewhere in the world, because of strong stakeholder and international research cooperation.

The developed individual tree segmentation and species classification capabilities have direct impact on improving corresponding tasks for nationwide forest resource inventories and management based on national laser scanning data (KALLIO program of several national governmental agencies), but also spill to industry targeting more automated forestry providing possibility to produce digital twins of forests based on these components. Multispectral reflectance information seems to provide additional performance benefit in numerous segmentation and classification tasks that could be developed using AI and deep learning methods.

6. EU-level impact

At the EU level, the project results can be considered very significant: forest damage risks and the uncertainties caused by them in decision-making in forestry have long been a significant threat to forestry in Central Europe. On the other hand, forest damage is linked to the development of forest biodiversity, meaning that from the perspective of the long-term sustainability of forests, damage is also an opportunity. The development of modern monitoring and decision-support methods is also a focus at the EU level.

7. Monitoring and evaluation

The main objective of the project has been to develop forest monitoring methods and risk management tools related to forest damage. The objectives and results of the project have a clear link to promoting the sustainable use and growth of Finnish and European forests.

With satellite databased methods, we can detect dead trees robustly over large areas, and using drones we can employ multitemporal inspections on such high-risk areas to support decision makers and forest owners in mitigation.

Spruce bark beetle is capable in destroying wide areas of coniferous ecosystems causing serious economical damage, but also changing landscapes significantly. The research gives answers how we could 1) manage risks, 2) manage forest resources and 3) detect impacts of SBB early to permit sustainable and timely management decisions.