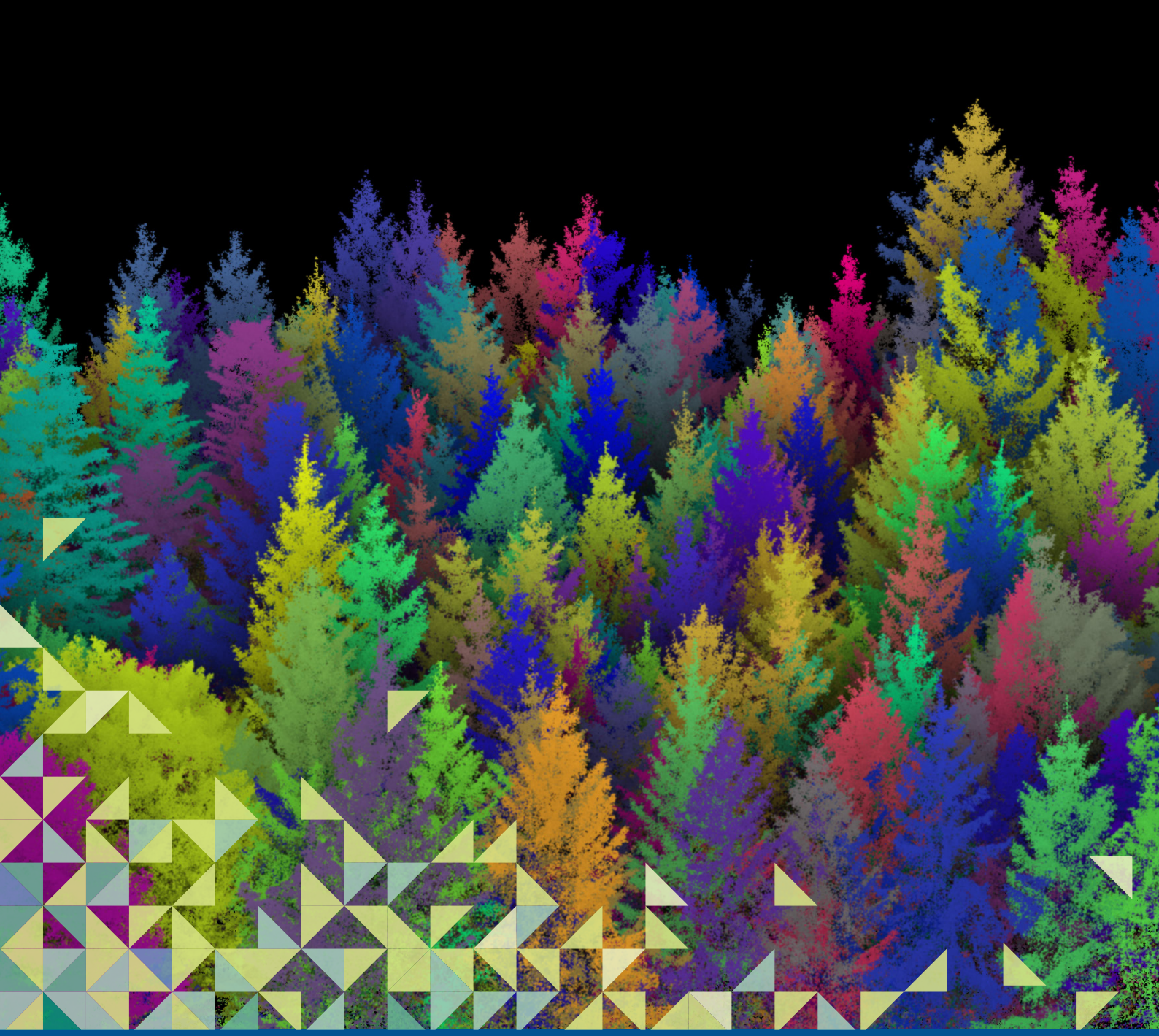


SMARTForest

Bringing Industry 4.0 to the Norwegian forest sector

Annual Report 2023

Contents

Front cover image: Stefano Puliti

Summary

SFI SmartForest is looking back on an intensive year 2023! The SmartForest consortium consists of the most important actors in the Norwegian forest sector, covering the value chain from the planted seedling to the mill gate, combined with leading research institutions in Norway and abroad.

We are a growing team which is fully enhanced in creating results from our activities to be used and implemented by our partners to achieve SmartForest's aim: to improve the efficiency of the Norwegian forest sector by enabling a digital revolution that transforms forest information, silviculture, forest operations, wood supply, and the overall digital information flow in the sector.

Some highlights from last year:

- To create innovation is one of the main credos for SFIs. In 2023, 6 new DOFIs were submitted for innovative solutions created within SmartForest.
- A demonstration area was established to develop and showcase the digital value chain by implementing technologies and methods developed in the various work packages. Here, data is collected along the value chain that is or will be integrated into our cloud-based platform, ForestSens. This demonstration area will, in the future, be able to illustrate the cumulative effect of digitizing a wide range of processes along the value chain.

The SmartForest team from research and industry in September 2023 gathered during the 2nd day of the SmartForest Days 2023 Image: Lars Dalen

- In 2023, we expanded our team and hired three Postdocs and three PhD candidates. Three master's students finished their studies within SmartForest.
- We continued the success with our internal conference "SmartForest Days" happening in September 2023, a lunch-to-lunch event with participants from all industry partners. The event was a platform for sharing research findings, discussing innovative ideas, and fostering collaboration.
- Several researchers were on "partner visits" at the industry partners within SmartForest for an even better understanding of the different needs and challenges of different partners and, at the same time, enhancing the understanding for collaboration possibilities.
- We established a meeting platform for the industry partners, the "Digitalization forum", a round table where partners meet regularly for discussion and collaboration on common solutions for a strong Forest-tech sector in Norway!

We are looking forward to a new, exciting year in SmartForest, and 2024 will be the year of scientific output and implementation of innovation, enhancing the partner's ambitions for applying technology and innovative solutions to support sustainable forest management in Norway. Follow us on our project webpage, on social media and our open webinars for a constant update of our work throughout 2024!

– Rasmus Astrup
Centre leader from SmartForest
host organisation NIBIO

The Research Council of Norway

Norwegian Centre for Research-based Innovation

NIBIO
NORWEGIAN INSTITUTE OF BIOECONOMY RESEARCH

Vision and objectives

Vision:

SmartForest will result in a long-term, world-leading, industry-focused R&D environment centred around the application of enabling technologies for the digital transformation of the forest sector.

The intended impacts are:

1. Ensure that the Norwegian forest sector will be managed using leading edge digital technologies.
2. Apply the emerging enabling technologies in the forest sector to create a series of innovations that can be operationalized and commercialized by the SmartForest partners.
3. Improve information, increase production efficiency, improve environmental efficiency, and overall increase value production from the forest-based value chain.
4. Improve the recruitment of professionals and young researchers in forestry.
5. Contribute towards the required green shift in the Norwegian industry by:

   (1) facilitating increased value creation and international competitiveness of the Norwegian forest sector, and

   (2) create the foundation for a Forest-tech sector in Norway.

Primary objective

The primary objective of SmartForest is to improve the efficiency of the Norwegian forest sector by enabling a digital revolution transforming forest information, silviculture, forest operations, wood supply and the overall digital information flow in the sector. The digital transformation will be enabled by a series of innovations that will form the foundation for the development of a strong Forest-tech sector in Norway.

Research plan and strategy

Working hypothesis:

SmartForest is the next leap in efficiency and environmental performance of the forest sector and will be enabled by digitalization and knowledge-based management.

SmartForest is divided in six work packages, and within each we have defined tasks which are annually updated.

WP1: Forest information

Focus in WP1 is the development of improved forest information. Combining data from emerging technologies can lead to significant improvement in forest information and create continuously updated and improved forest information for a much broader spectrum of variables than in today's forest inventories.

WP leader Erik Næsset

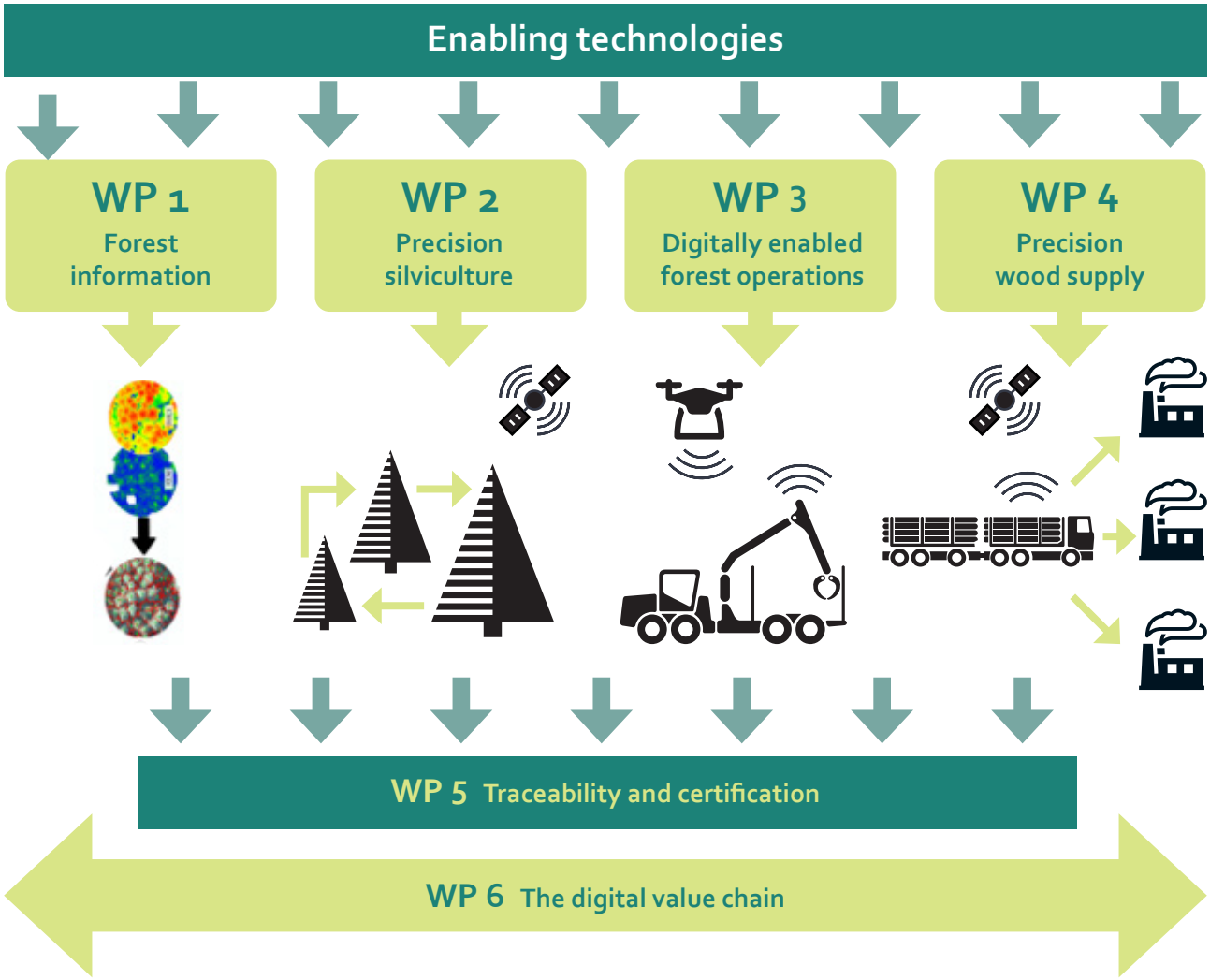
Erik Næsset is a professor in remote sensing and forest inventory at the Norwegian University of Life Sciences (NMBU), Faculty of Environmental Sciences and Natural Resource Management, in Ås, Norway. Næsset›s research focuses on using remote sensing and other geospatial technologies for forest inventory and monitoring.

WP2: Precision silviculture

WP2 focuses on cost-efficient precision silvicultural practices that can increase the growth rates of Norway's forest. Through application of the emerging technologies precision silviculture will provide operationally feasible and cost-efficient production gains.

WP leader
Kjersti Holt Hanssen

Kjersti Holt Hanssen is a researcher at the Norwegian Institute of Bioeconomy Research (NIBIO), Department of Forest Management, in Ås, Norway. Her research focuses on silviculture, particularly related to forest regeneration, fertilization, and other nutrient issues.



WP3: Digitally-enabled forest operations

Main focus in WP3 is the improvement of forest operation efficiency and avoidance of environmental damage through the application of emerging technologies.

WP leader Heikki Korpunen

Heikki Korpunen is a researcher at the Norwegian Institute of Bioeconomy Research (NIBIO), Department of Forest Operations and Digitalization, in Ås, Norway. His research focuses on developing evidence-based strategies for improving forest operations and logistics.

WP4: Precision wood supply

WP4 focuses on the development of precision wood supply approaches that reduce the costs of logistics, reduce seasonal fluctuations in wood supply, and increase the value creation of the harvested wood. By applying emerging technologies, precision wood supply, where supply and demand are matched with respect to time and quality, can be optimized.

WP leader Stephan Hoffmann

Stephan Hoffmann is a researcher at the Norwegian Institute of Bioeconomy Research (NIBIO), Department of Forest Operations and Digitalization, in Ås, Norway. His research focuses on timber harvesting and transport, forest wood supply chains, forest road engineering, ergonomics and occupational health and safety.

WP5: Traceability and certification

Using forest machine data, traceability technologies, and sensors along the value chain will allow for full traceability throughout the value chain and enable semi-automatic reporting for certification and virtual audits.

WP leader Hans Ole Ørka

Hans Ole Ørka is a researcher at the Norwegian University of Life Sciences (NMBU), where he works in the Faculty of Environmental Sciences and Natural Resource Management. His research covers topics related to forest inventory and remote sensing, such as the use of airborne and spaceborne sensors for forest management planning and ecological applications.

WP6: The digital value chain

Large efficiency gains can be achieved by enabling the digital value chain. WP6 will enable a fully digital flow of information between the key private and public actors in the forest sector through the development of a series of applications and APIs that connect the different actors in the value chain.

WP leader Terje Gobakken

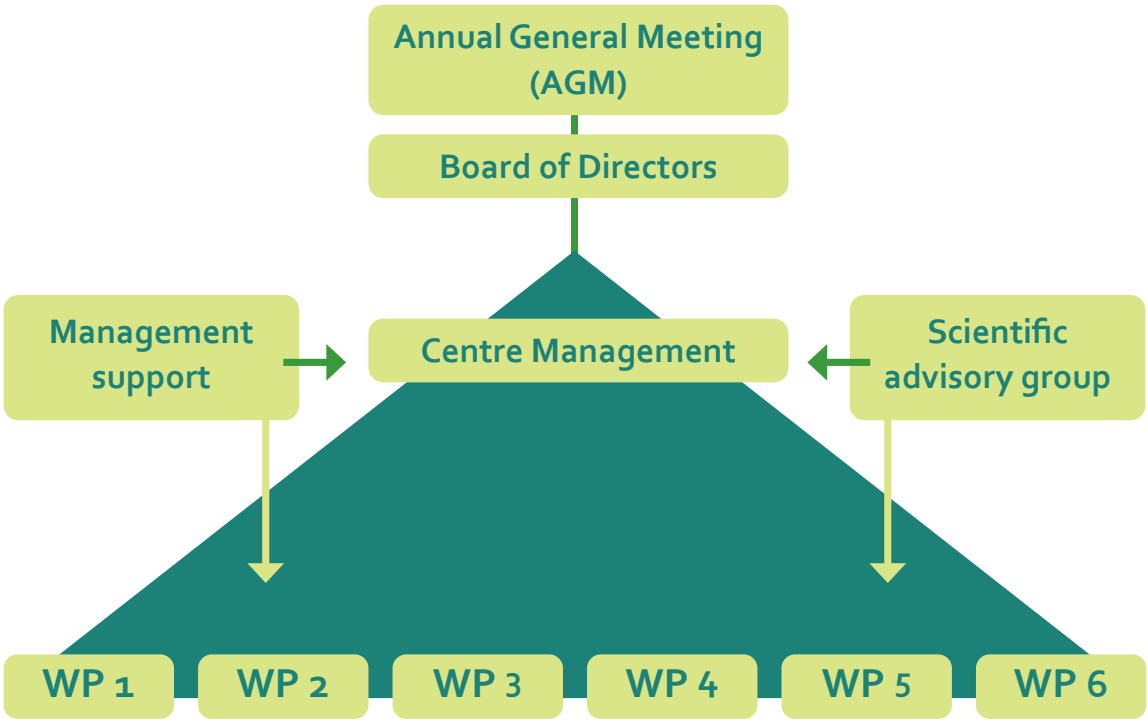
Terje Gobakken is a professor at the Norwegian University of Life Sciences (NMBU), Faculty of Environmental Sciences and Natural Resource Management, in Ås, Norway. His main research area is forest inventory and remote sensing, with a particular focus on using remote sensing technologies for forest monitoring and management planning.

Organisation

Organisational structure

The Annual General Meeting convenes once a year to discuss the centre's activities, present result highlights from the past year and discuss forthcoming plans. The board is the ultimate decision-making body of the consortium.

The scientific advisory group ensures the centre's excellence and consists of Franka Brüchert, FVA (Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg), Department of Forest Utilisation; Bruce Talbot, Stellenbosch University, Dept. of Forest and Wood Science and Juha Hyppa, National Land Survey of Finland, Remote Sensing and Photogrammetry.



Board Members 2021–2025


Chair

Anders Øynes, CEO AT Skog SA
Monica Grindberg, Forest Director Statskog (Deputy)





Board members (from left)

Gudmund Nordtun, CEO Glommen-Mjøsen Skog
Leif Erik Blankenberg, Technical Manager and Head of R&D Department at Field Group
Tor Henrik Kristiansen, CEO Viken Skog SA
Arne Rørå, CEO Norskog (Deputy)
Lars Storslett, Director Moelven Virke AS (Deputy)


Board member NMBU

Hans Fredrik Hoen, Dean NMBU-MINA
Jan Vermaat, Research Dean NMBU-MINA (Deputy)


Board member NIBIO

Bjørn Håvard Evjen, Division leader NIBIO
Per Stålnacke, Research Director NIBIO (Deputy)

Centre Management Group

Centre Director

Rasmus Astrup, NIBIO

Vice Director

Terje Gobakken, NMBU

Centre Coordinator

Carolin Fischer, NIBIO

Administrative Support

Kristian Fæste, NIBIO

Eva A. Haugen Johnson, NIBIO

Centre Communication

Katrin Zimmer, NIBIO

Innovation Manager

Jorun Pedersen, Ard Innovation

Johan Biørnstad, Ard Innovation

Partners and partners' role in SmartForest

Forest management and owners' associations

Viken Skog, **Glommen Mjøsen Skog**, **AT Skog** and **Norskog** represent over 35 000 forest owners. Together with **Statskog**, the forest owner associations are the primary implementers of inventory, silviculture, forest operations and timber sales (90% of the Norwegian timber production). In SmartForest, these organizations identify bottlenecks or areas needing R&D focus and implement the SmartForest innovations in the forest-based value chain. The forest managers and owners will simultaneously be responsible for providing access to study sites and existing data streams generated in the value chain. **The Norwegian Forest Owners' Federation** (NFF) are respon sible for a large part of the communica-tions activities targeted at the sector and towards the policy system.

Machine manufactures and contractors

Komatsu Forest supports the project with access to machine data, which is a key enab-ling technology applied heavily in the forest information WP and in the digital operations WP. Komatsu Forest supports integrating new sensor and automation systems in actual operational forest machinery but also allows some of their R&D engineers to collaborate on aspects related to the automation of key forest operations.

MEF represents the machine owners in SmartForest. The machine owners' role in the project is to give access to machine-captured data but also play a central part in developing the digital value chain by testing and evaluating innovations related to digitally enabled forest operations.

Technology, data and service providers

Field group, Skogdata, Norsk Virkesmåling, and Skogbrand play an inherently active role in the Centre.

Field group is a leading remote sensing company and participates in data capture and the development of novel drone and remote sensing implementations for improved forest information.

Today, **Skogdata** facilitates the digital flow of information between buyers, sellers, and transportation organizations and participates in developing and implementing the digital value chain. Skogdata is central for accessing existing data streams and implementing innovation in the digital value chain.

Norsk Virkesmåling, the organization responsible for measuring harvested timber, participates actively with the ambition to completely revolutionise how timber is measured (volume and quality) in Norway.

Skogbrand is the only insurance company specializing in forests in Norway and focuses on utilizing continually updated forest information obtained through remote sensing and drones to better assess damages for insurance payments and utilization of the generated data to better estimate risk.

Biodrone specialises in drone services within the forestry and agricultural industry. Within SmartForest, they participate in data capture of drone laser data.

Ard Innovation contributes to increased value creation based on research, innovation and expertise and carries out innovation management for the Centre.

Sawmilling industry

Moelven Virke represents the timber buyers and mills in SmartForest. Moelven Virke plays a central part by ensuring that we can link the individual tree in the forest to the actual products and value that is output from the mill. This will be done by facilitating access to data from X-ray frames in the mills and product breakdown of the individual logs. Further, Moelven is central in evaluating how better information on quality and production can be utilized to better match demand and supply and, in this way, increase the value creation given the same timber production.

Moelven

Public sector

The public sector plays a central role in the digitalization as public and private systems must develop and correspond to make for a seamless integration of monitoring and reporting. In SmartForest, the public sector is represented by the **Norwegian Agriculture Agency (Landbruksdirektoratet)**, who will participate in developing the public systems to match the digitalization of the private sector.

Landbruksdirektoratet
Eanandoallodirektoráhtta

Research partners

The classic forest research partners **Norwegian University of Life Sciences, Faculty of Environmental Sciences and Natural Resource Management (NMBU-MINA)** and the **Norwegian Institute of Bioeconomy Research (NIBIO)** are complemented by researchers from the **NMBU Data Science program (NMBU- Faculty of Science and Technology)** to support technical developments, Big Data handling and advanced analysis. Further, statisticians from the **University of Oslo (UiO)** and its research centres **OCBE/BigInsight** are included in SmartForest to provide internationally leading methodological competence in advanced analysis, big data and machine learning.

NIBIO
NORWEGIAN INSTITUTE OF BIOECONOMY RESEARCH

N M B U
Norwegian University of Life Sciences

UiO : Universitetet i Oslo

International cooperation

The digitalization of the forest sector is a global and fast-moving phenomenon where it is key to stay oriented on the state-of-the-art and developments from around the world. Hence, the main objective of the international collaboration in SmartForest is to ensure that the Norwegian forest sector both gains and stays at the absolute forefront of the international research frontier and, at the same time, uses the platform to attract some of the most promising R&D talents.

Therefore, we collaborate with three international research partners leading in different aspects of industry-focused R&D related to the digitalization of the forest sector in SmartForest. The three partners are:

1. **The Mistra Digital Forest** is a similar program to SmartForest on digitalization in the forest sector in Sweden. Mistra Digital Forest and SmartForest collaborate on developing new educational offerings at the master's and PhD levels. The forest sector faces a significant challenge in recruiting new students, and we hope to attract more students in the future with new educational offerings.

Collaboration has also been established towards improved taxation data from forestry and data assimilation, as well as biodiversity mapping using lidar and logging machine data. Furthermore, Mistra Digital Forest is part of the sub-project on traceability of individual timber.

2. **FPInnovations** from Canada, with its Forestry 4.0 initiative, is a partner in SmartForest. We collaborate on the simulation and development of autonomous forest robots. Furthermore, we are working with FPInnovations on using drone data and deep learning in forestry.

3. **The RIF Institute for Research and Transfer e.V.** in Germany is part of KWH4.0, Center of Excellence for Forestry 4.0, which works with digitalization concepts in the forestry and timber sector. RIF developed a digital twin for forests. In collaboration with RIF, we have created a digital twin for an area in Oslo municipality forests, where we are now redefining the parameters for various simulations and integrating the forest robot. The digital twin can, for example, be used to simulate, evaluate, and optimize logging processes.

All three international partners are committed to facilitating researcher exchange and co-organising meetings and workshops. This ensures that SmartForest researchers and user-partners more rapidly arrive and remain on the research frontier. Further, the international partners contribute with key competencies in selected R&D activities that improve the overall quality of the innovations developed.

Furthermore, SmartForest encourages international collaboration also with international researchers outside of the partner organizations through our existing large international network.

Mistra Digital Forest

FPInnovations MC

RIF Institut für Forschung und Transfer

Scientific activities and results

Some highlights of the scientific activities and results of the different Work Packages.

Is image matching as good as airborne laser scanning?

Point clouds constructed from aerial images using digital photogrammetry (DAP) have gained substantial attention for the purpose of forest inventories, mainly because the acquisition of images is less costly than acquiring airborne laser scanning (ALS) data. However, studies have indicated that estimated forest characteristics using DAP point clouds are less precise compared to those estimated by means of ALS point clouds. The trade-offs between precision and cost-effectiveness may still render DAP a viable alternative for certain applications in forest inventory. With a multitude of possible combinations of image qualities and software for processing, care should be taken before implementing DAP point clouds in forest inventory pipelines. This Smart-Forest task has systematically tested the accuracy and precision of modelling forest characteristics using metrics representing point clouds constructed using five different software tools for matching images. The results were compared to the results obtained by using ALS metrics.

For different modelling alternatives, the root mean square error (RMSE) between field reference values of stand basal area, volume, Lorey's mean height, dominant height, and number of stems, and corresponding model

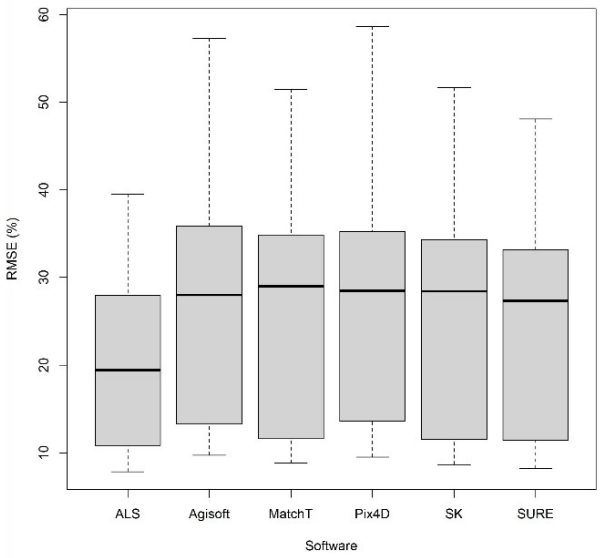


Figure 1. Boxplots of the distribution of RMSE (%) resulting from modelling forest characteristics using different point clouds. Image: Ole Martin Bollandsås

fitted values (model residuals), was on average smaller using ALS (median RMSE ≈ 20%) compared to all models based on metrics obtained by all DAP-software packages (median RMSE ≈ 30%). The results are illustrated in Figure 1, displaying the distributions of the relative RMSEs for 15 models (5 forest characteristics, 3 strata) based on each of the different point clouds analyzed. ALS was ranked as number 1 in terms of RMSE (smallest RMSE), 11 of 15 times, most often followed by data extracted using the DAP-software SURE (Table 1). The results also indicate (not displayed) that the different DAP point clouds yielded RMSE values closer to ALS for the height characteristics compared to the other characteristics.

ALS /	Rank					
Software	#1	#2	#3	#4	#5	#6
ALS	11	2	1	1		
SURE	2	10	1	2		
SK	1	1	7	4	1	
MatchT		2	3	6	1	2
Agisoft			2	1	8	4
Pix4D	1				5	9

Table 1. Count of ranks (1-6) based on RMSE (%), for models dependent on metrics representing height distributions of point clouds from ALS and different DAP software.

Breaking the results down to the level of each characteristic also shows that DAP point clouds yield results with larger variation. There were also several field plots used in this study, for which several of the DAP software packages were not able to create point clouds at all. There were also clear differences related to image quality. Figure 2 displays cross sections of three DAP point clouds (lower three) matched using different software and image quality, and an ALS point cloud (upper). Panel B and D both display point clouds from using Match T, but with different image quality, with a striking visual difference. Differences are also clearly visible between software and ALS (panels A-C).

Considering that the demand for forest inventories to provide more detailed information in the future, for example height variation and crown lengths in relation to continuous cover forestry, we still consider that ALS is the more reliable source of remotely sensed data.

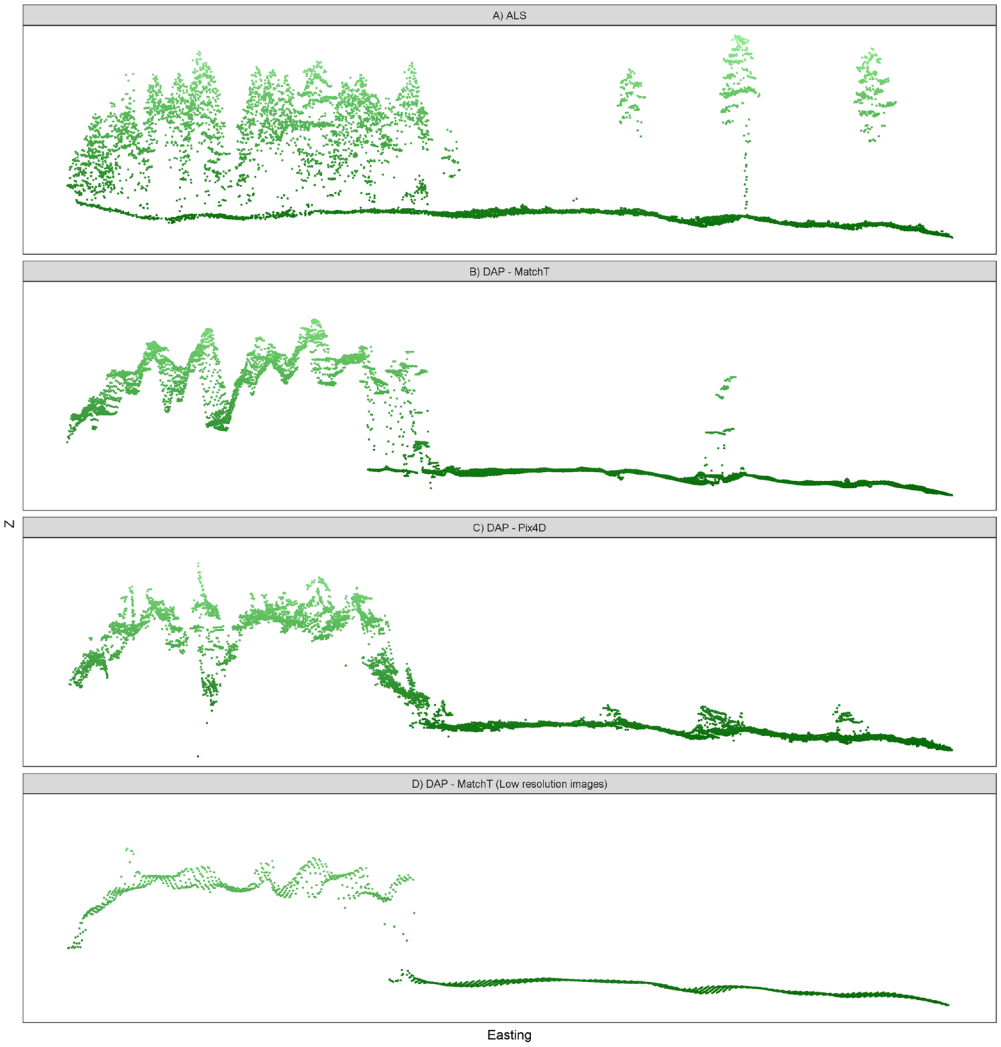


Figure 2.
Cross sections of four point clouds constructed using different DAP software and image quality, compared to an ALS point cloud.
Image: Ole Martin Bollandsås

Site classification for tree species suitability mapping

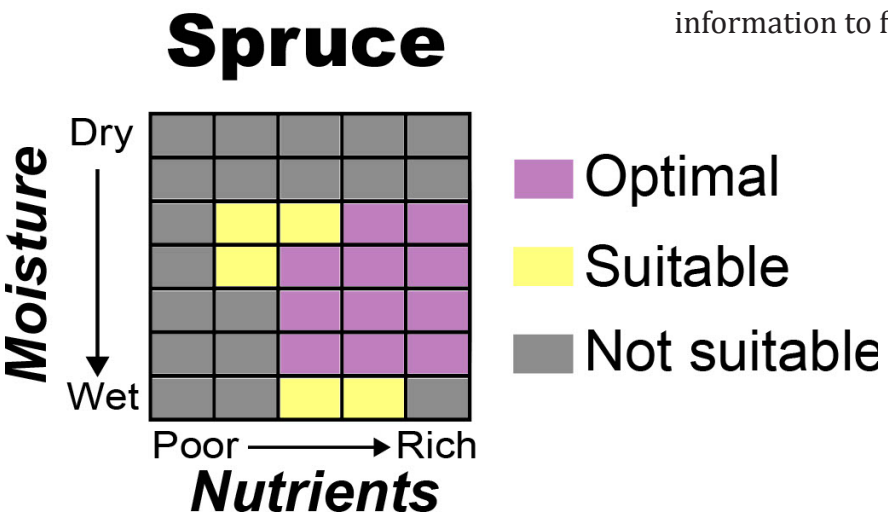
Our goal is to support precision silviculture with digital tools. In this task, we consider that the basis of successful silviculture is the preferential use of site adapted tree species. At present, there are no species suitability maps available in Norway to help ensure that we have the right species in the right place in the future, which is particularly important for forest regeneration.

Assuming we are within a given climate zone and the light requirements are met, the suitability for a particular species is based on soil nutrient availability and the available water content. Taking inspiration from techniques used in Canada, Scotland and Denmark, we have created a simplified assessment system, based on terrain features and visible assessments of soil by gouge auger. The assessment aims at categorisation of soil moisture content and nutrient availability, so that a species can be selected based on the resulting combination of these two variables. For this purpose, we have derived edaphic graphs (one per species) that match the categories of our classification matrix (Figure 3). These edaphic grids will help decide which of the main tree species is the best choice at a specific location (Figure 4). Therefore, once the moisture and nutrient status are known, an informed decision about species can be made.

Figure 4. Pine, spruce, or perhaps birch? Making the right species choice is important.
Image: Kjersti Holt Hanssen

The categorisation system will be tested during 2024 for a range of site conditions. The idea is not to use this at the forest-stand level but to carry out many tests within a stand because within-stand variability can be considerable. When we have sufficiently tested and refined the basic system, we will attempt to build and test appropriate technological solutions to provide the required information to forest managers.

Figure 3. So-called edaphic grids allow species to be selected according to a classification system for soil nutrient and water availability. An example is shown here for spruce in Norway. This example is derived from a combination of NFI data and expert opinion.
Image: Paul McLean



Road geometry detection through RoadSens

Technical classification of forest roads is essential to facilitate efficient supply chains and to know about constraints towards vehicle type and seasonal trafficability. Road geometry, reflected in the horizontal, vertical, and cross-sectional alignment of roads, provide key variables for technical classification, as for example according to the Norwegian standard for agricultural roads (Veinormaler for landbruksveier). Since many forest roads have been built in the 1960s, with partly poor documentation, technical classification is often not correct, and many roads have never been classified, or in some cases even mapped. Conventionally, roads need to be surveyed in-field in a time intensive and costly manner to capture this information and fill up the gaps in road data bases. The RoadSens platform overcomes this challenge by providing a flexible to use proximal sensor platform for automatic road geometry detection.

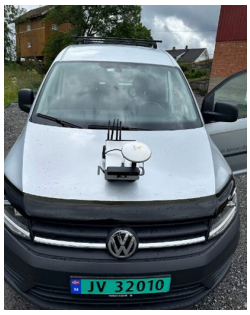


Figure 5. RoadSens platform attached to a passenger car. Image: Helle Gobakken.

The platform consists of a stereo-camera, GNSS receiver and antenna, communication module and a GPU-powered edge computer, fitted in a rugged and compact housing with magnetic mounts, quickly to be exchanged among vehicles. Functional control of the platform is provided through a web interface accessible via any mobile device browser.

During operational traffic with a speed of approximately 20 km/h, the sensor platform records the roadway with the stereo-camera and geo-references the video frames through the GNSS antenna. An object detection model based on the YOLOv8 algorithm was trained

Figure 6. RoadSens footage with the masked roadway. Image: Mostafa Hoseini

to detect and mask the roadway in the footage as a first part of the data processing flow. This is followed by a point cloud generation of the captured road to receive a 3D model of the road section visible in the video frame. Merging the roadway mask with the point cloud, allows to generate georeferenced 2D cross-sectional profiles of distinct points of the surveyed road.

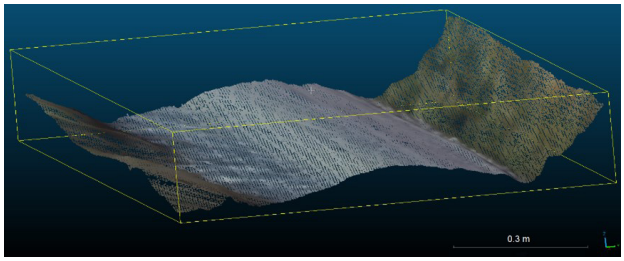


Figure 7. 3D road section generated through the stereo-camera based point cloud (height multiplied by 2). Image: Mostafa Hoseini

From these profiles, road geometry features such as the road width and centreline location can be extracted. Subsequently, the gradient for vertical alignment and the curvature for horizontal alignment can be determined. In addition, the cross-sectional profile allows to evaluate further road geometry parameters such as sidefall or cross-slope and road-side ditch dimensions to complete the classification related list of features.

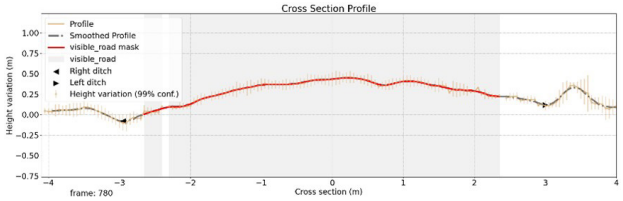


Figure 8. 2D Cross-sectional profile with dimensions of detected road features. Image: Mostafa Hoseini

Improved trafficability assessment through a national moisture map

The planning for efficient harvesting operations at minimized environmental impact is dependent on information about a site's ground bearing capacity and susceptibility to off-road vehicle induced soil impact. Mechanical soil strength is related to soil type and structure, but also moisture, which is subject to seasonal change and highly affected by topography. More precise information on soil moisture behaviour supports scheduling of harvesting operations according to seasonal restrictions, or during the experience of unusual weather conditions such as intensive rainfall events, by estimating the mechanical strength of harvesting grounds. In addition, such information are also important constraints within forest road alignment planning.

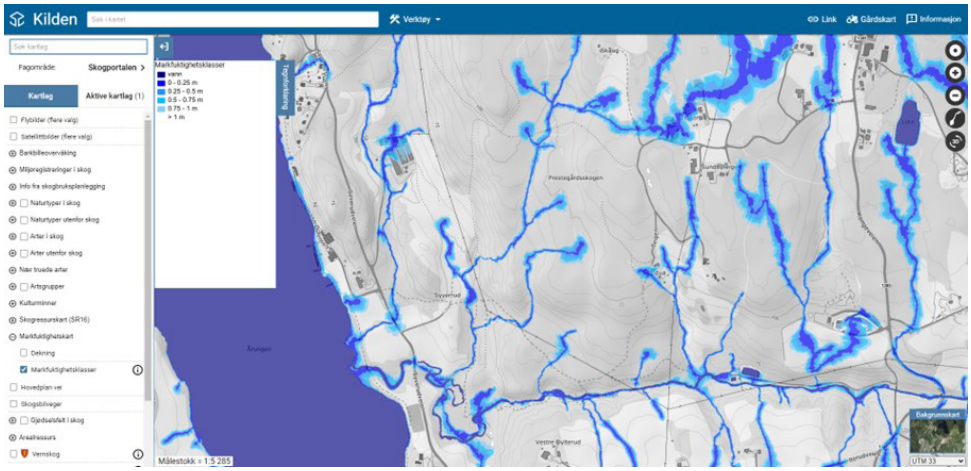


Figure 9. DTW maps with classes (Markfuktighetsklasser) provided through the Kilden portal

Spatial information generated with the DTW (depth-to-water) algorithm represent raster data with height differences from one point to nearby water-saturated points, indicating areas of high soil moisture content. This information is for example one of the input variables for the end-user tool Timbertrail, tested in Task 3.4, to optimize forest machine path on an operation site. In general, moisture maps generated with the DTW algorithm were acknowledged as an effective operational planning tool, but also depend on the resolution of the input DTM (digital terrain model). Thus, constant efforts have been undertaken to improve DTW maps and make them available to stakeholders.

NIBIO started to make moisture maps available to users through its portal Kilden, named "markfuktighetskart" (Figure 9). There, the maps are available and can be downloaded in two forms. First, as a ground moisture DTW map, a raster with the vertical distance in cm from points to nearby water-saturated points and in addition as a raster representing these differences in seven classes of ground moisture. The resolution of the DTW maps is depending on the resolution of the input DTM. With its first version, the DTW maps were based on the availability of the Norwegian 1x1 m DTM as at status of 2018, which did not cover all the country and was substituted with the available 10x10 m DTM. These ones have been updated and improved with the now overall available 1x1 m DTM, including a better consideration of water bodies of different magnitude, and will be made available on Kilden in 2024.

The availability of high resolution DTW maps across the country allow to further integrate them now widely into operational planning routines to mitigate environmental impacts caused by timber harvesting operations. It is the aim to further improve these maps to make them available in a dynamic manner to further account also for seasonality aspects.

Retention trees and the necessity of data sharing

According to the Norwegian forest certification systems, a minimum of 10 retention trees per hectare of the harvested area must be set aside when harvesting. These retention trees can be left either individually or in groups within the operational area in a manner that contributes to tree stability. The requirement for the number of retention trees is applied as an average across the harvested area, which may encompass multiple forest stands.

The last update of the certification systems state that these retention trees should be mapped in connection to the harvest. It is further mandated that, upon establishment of a central database for retention trees, these trees must be reported. Making information about retention trees accessible across organizations prevents situations where trees conserved by one operator are mistakenly cut by another. Furthermore, a shared database plays a crucial role in monitoring retention trees over time.

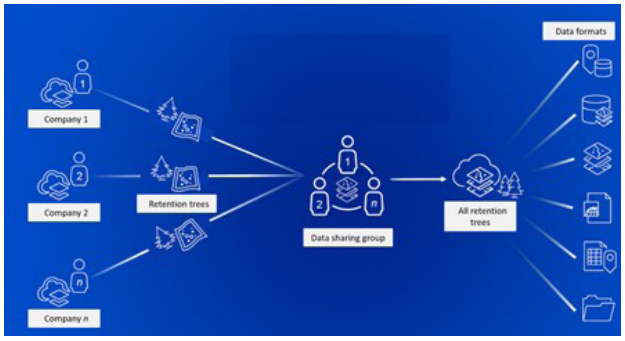


Figure 10. Distributed databases for retention trees

To aid in fulfilling the certification requirements, SmartForest has developed a distributed database system for sharing retention tree data (Figure 10). The implementation of this system is currently underway, and data for about 100,000 trees from four of the partners are now accessible in the database prototype in real-time. The next phase

Figure 11. Retention tree and drone data acquisition.
Image: Svein Dypsund

involves updating the prototype with features for storing additional attributes about the retention trees and implementing improved functionality for editing. Nevertheless, this innovative system is ready to be fully implemented and utilized by operational forestry.

To enhance the quality of data on retention trees in our partners' databases, we are conducting comprehensive research within SmartForest. We are developing methods to map retention trees by harvesters during the harvest, post-harvest by remote sensing methods and even providing suggestions for retention trees before harvest. The capturing and sharing of environmental information between SmartForest partners exemplified with retention trees could be expanded to other environmental data. This effort aims to provide more accurate and reliable information to support better forest management practices.

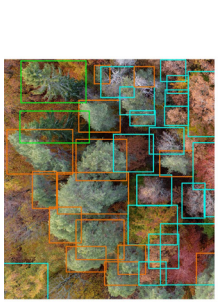
Education

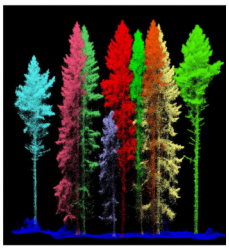
Teaching

NMBU, NOVA University network Deep Learning Applications in Forest Remote Sensing Applications with Examples in Python

NMBU, as part of the NOVA university network, hosted the "Deep Learning in Forest Remote Sensing Applications with Examples in Python" course from May 22 – 26, 2023, in Ås. This SmartForest initiative focused on the increasing use of deep learning techniques in forest remote sensing. The course provided theoretical and practical knowledge on using deep learning to solve common forest remote-sensing tasks, focusing on image and point cloud data. Lectures were delivered by Stefano Puliti, Maciej Wielgosz, and Rasmus Astrup from NIBIO. The course, conducted in English, aimed to enable participants to develop their own deep learning models and was targeted at students and researchers in related fields. It included pre-course self-study, in-class work, and a post-course home exam. The course content covered deep learning methods, tasks, and deployment.

https://www.forestinventory.no/wp-content/uploads/2023/03/forest_deepLearning_2023_syllabus_v3.pdf



NMBU, MINA 305 Remote Sensing in Forest and Natural Resource Management

Through SmartForest, NMBU, with Hans Ole Ørka, developed and conducted a course in the fall semester of 2023, focusing on the application of remote sensing in forest and natural resource management. The course provided a comprehensive understanding of the use of remote sensing in mapping, monitoring, and analyzing ecosystems, particularly forest ecosystems. It covered various types of sensors and platforms for data collection, their specific characteristics, and application areas. The course also went further into different methods for analyzing and using remotely sensed data in forest and nature mapping and the use of sample-based surveys. The aim was to equip students with robust theoretical and practical knowledge of collecting, processing, and using remotely sensed data for terrestrial ecosystem

mapping, assessment, and monitoring. The course will be a permanent addition to the Faculty of Environmental Sciences and Natural Resource Management curriculum portfolio at NMBU.

https://gammel.nmbu.no/course/MINA305

Solør Videregående School Workshop on NIBIO research activities (06.12.2023)

Solør Videregående School, department Sønsterud, which offers specialized education for forest operators, recently hosted a one-day workshop by Johannes Rahlf. The workshop, focusing on activities within SmartForest and the Norwegian National Forest Inventory, included theoretical introductions and practical exercises in the forest. Throughout 2023, we maintained continuous contact with the school, visited several times, engaged students in the field activities in the area, and updated them on the work within the centre.

Such collaborations are highly beneficial as they bridge the gap between academic research and practical application. They provide students with hands-on experience and a deeper understanding of the theoretical concepts taught in class. Moreover, these collaborations allow the students to gain insights from the ongoing practice of forest operators, fostering innovation and ensuring the recruitment of young motivated students. This symbiotic relationship ultimately contributes to the advancement of sustainable forestry practices.

Student internships and student summer jobs

Summer work and internships provide invaluable opportunities for students to gain practical experience in their field of study. This year, Ingvild Sandvin Groven, NTNU, Aydin Barış Ustun, NMBU and Vincent Baur, University of Freiburg complemented our team through summer jobs and internships.

Ingvild and Vincent collected GeoSLAM data with a backpack for forest monitoring. Vincent also collected georeferenced data for developing AI tools to monitor forest road conditions and maintenance needs. Both datasets required annotation work performed by the students.

Barış worked on the ForestSens team, a cloud-based platform within the Oracle Cloud Infrastructure. His role focused on enhancing user experience and platform functionality. He designed a data-driven user interface, managed dashboards, and developed data visualization elements, including interactive reports and maps, contributing to more effective data presentation.

Vincent Baur, University of Freiburg, Ingvild Sandvin Groven, NTNU and Fride Høistad Schei during fieldwork enjoying lovely Norwegian summer.
Image: Stefano Puliti

Like those undertaken by Ingvild, Vincent, and Barış, summer work and internships create a mutually beneficial relationship. Students gain hands-on experience and practical skills, while our team benefits from their fresh perspectives and contributions to key projects. This collaboration not only advances our work but also helps shape the future professionals of the forest sector.

Phd candidates and Postdocs

During 2023, 7 PhD students and 5 Post-doctoral fellows were working on topics related to the Centre topics, of whom 6 started their position throughout the year.

OLHA NAHORNA

Institute: NMBU
Position: PhD candidate
Project period: 2022–2025
Topic: Assessing the importance of accurate forest data in forest planning and decision-making processes

My PhD is focused on evaluating the importance of accurate forest data for decision-making. Over the last year, my work was focused on evaluating the value of information using stochastic programming for a variety of airborne laser scanning based inventory approaches. We studied the importance of accurate inventory data depending on management objectives (maximizing total net present value or minimizing the risk of not meeting specified periodic income targets) for a range of targets and decisionmaker's risk preferences. The paper was finalized and is currently under review with the journal. The results of the study showed that the value of information would vary depending on the management goals. Overall, inventory approaches that provide higher quality data provide the best performance for the whole range of targets and risk preferences. Nevertheless, less precise inventory approaches could be sufficient if management goals are focused only on one extreme objective. Additionally, I have successfully completed my planned PhD coursework and earned all the planned study credits.

YOHANN JACOB SANDVIK

Institute: NMBU
Position: PhD candidate
Project period: 2022–2025
Topic: AI for timber measurement

My PhD is centered around the application of machine learning techniques to automate tasks within forestry. In 2023, I focused on the project of computing the encompassing bounding box of log piles to get an estimate of the wood volume of the pile. This project was done in collaboration with Norsk Virkesmaaling. In addition, I have been working on a project of detecting and automatically tracking codes printed to log faces using object detection and optical character recognition. Both projects are continuing into 2024.

JAIME CANDELAS BIELZA

Institute: NMBU
Position: PhD candidate
Project period: 2022–2025
Topic: Enhanced forest inventory information for operational planning

In 2023, my research focused on estimating tree species proportions using different combinations of remotely sensed data (ALS, aerial and Sentinel-2 imagery) to find the most accurate combination. I completed and submitted my first paper on this topic, which is now under review. The findings of the paper were that the ALS, in addition to Sentinel-2 imagery from at least two seasons, outperformed the rest of the remotely sensed data combinations. I presented part of the results at the SILVILASER conference that took place in London. During 2023, I finished my necessary credits and started to work on a second paper that compares various methods for species proportion estimation, aiming to determine the most accurate and efficient techniques for it.

MARIA ÅSNES MOAN

Institute: NMBU
Position: PhD candidate
Project period: 2021–2024
Topic: Improving methods for site index estimation by using remote sensing

I am doing a PhD in site index determination using remotely sensed data. In spring 2023, we published a paper on the classification of areas suitable for site index determination. Otherwise, my focus has been on completing a study on the use of time series data, i.e., remote sensing data from more than two points in time, for site index determination, and planning and collecting data for a study on the prediction of top height development (and site index) in young spruce forests from branch whorls detected with a deep learning model.

JULIUS WOLD

Institute: NMBU
Position: PhD candidate
Project period: 2023–2026
Topic: Natural forest mapping with deep learning methods

The main goal of the PhD is to apply deep learning methods for mapping natural forest. Currently, I am looking at the use of historical aerial photographs for extracting the extent of clear-cuts through time. By utilizing deep learning methods on historical images, we can extract unique information and improve the accuracy of natural forest mapping compared to existing methods.

HÅKON NÆSS SANDUM

Institute: NMBU
Position: PhD candidate
Project period: 2023–2026
Topic: AI and deep learning in forest inventories

My PhD project, initiated in the latter half of 2023, focuses on leveraging deep learning and artificial intelligence for forest inventories. With a background in forest science and no prior knowledge of these cutting-edge technologies, the initial six months of the project were dedicated to intensive coursework on the subjects of deep learning and artificial intelligence. Concurrently time was put into exploring relevant studies to guide the direction of the project. As a result, the first study is set to unfold throughout 2024 and will explore the possibility of implementing deep learning into the process of delineating forest stands.

HELLE ROSS GOBAKKEN

Institute: NIBIO
Position: PhD candidate
Project period: 2023–2026
Topic: Forest Roads

I am working on developing, applying, and validating methods and technologies to improve the efficiency of forest road management in Norway under the consideration of a competitive and transitioning timber sector, increased societal environmental awareness and climate change induced extreme weather. So far in the PhD project, I have focused on the collection of geometry data from forest roads using the mobile proximal sensing platform RoadSens. The goal is to evaluate the efficiency of these data in classifying the forest roads according to the national forest road standards and seamlessly integrate the output data in the ForestSens cloud service for easy access and interpretation.

MACIEJ WIELGOSZ
Institute: NIBIO
Position: Post-doctoral fellow
Project period: 2022–2025
Topic: Semantic and instance segmentation of forest using LiDAR

In 2023, my work primarily centered around enhancing point cloud analysis through deep learning. My focus areas included developing more resilient features for instance and semantic segmentation, designing, and executing end-to-end deep learning models for these segmentation tasks, and optimizing pipeline operations for handling extensive point clouds. I also dedicated efforts to establish a production pipeline that incorporates these models for practical application in instance and semantic segmentation of point clouds. Additionally, my work involved deploying these models as a service in the Oracle cloud. Throughout the year, I published two papers, and one is in the second round of the review process.

MOSTAFA HOSEINI
Institute: NIBIO
Position: Post-doctoral fellow
Project period: 2022–2025
Topic: Sensor solutions for digital forestry

As a postdoctoral researcher in the SmartForest project, my main focus in 2023 was on several tasks: firstly, co-authoring a paper titled «Pothole detection in the woods: a deep learning approach for forest road surface monitoring with dashcams». Secondly, I was involved in developing control and manage-ment programs for SmartForest devices. Thirdly, I worked on creating the first prototype of Road-Sens, a device designed to measure and monitor forest roads. I also have worked on MillSens, a tool for estimating sawlog outer-shape geometry using stereo camera data. Furthermore, I contributed to four presentations at the FORMEC 2023 conference in Italy.

Master thesis

Helga Sofie Gisholt Jønland
Tree species classification with Sentinel-2 time series, laser data and climatic variables through random forest. NMBU.

This master's thesis presents the exploration of multispectral satellite images, climatic variables, and laser data to identify specific tree species using the machine learning algorithm, random forest. The study reveals a promising model for classifying spruce species within a restricted geographical area and two less precise models for detecting oak and grey elder among deciduous trees. Climatic variables played a significant role in all models, while laser variables did not significantly improve the models.

Håkon Næss Sandum
Effekten av redusert arealdekning av tilgjengelig beregningsceller på presisjonen til bonitetsestimat ved anvendelse av direkte metode for skogbonitering. NMBU.

Sandum's Master's thesis aimed to examine the impact of reduced area coverage on the prediction of site index in Norwegian forests using the direct method based on the implementation of airborne laser scanning data. The research involved an intensive simulation, revealing that the standard error decreases with increasing sampling fraction. However, the number of iterations was sufficient only in about half of the simulations. The study also highlighted the need for further research to account for spatial autocorrelation in spatial data. Despite certain limitations, the research provides valuable

MORTEZA DANESHMAND

Institute: NIBIO
Position: Post-doctoral fellow
Project period: 2023-2025
Topic: Sensor solutions for digital forestry

Morteza Daneschmand's work on sensor solutions for digital forestry is linked to digitally enabled forest operations. He uses machine vision and learning to analyze data from LiDAR sensors, which helps detect trees and understand the specific operations performed by the harvester head.

FATEMEH NOROOZI

Institute: NIBIO
Position: Post-doctoral fellow
Project period: 2023-2025
Topic: Sensor solutions for digital forestry

Fatemeh Noroozi is associated with the group focusing on sensor solutions for digital forestry. One of Fatemeh's key projects involves machine learning and image recognition tasks within SmartForest, where she works on developing learning-based systems for the automated recognition of branches in different seasons. Applications can be, for example, damage registrations after a windfall or snow break.

MARIE-CLAUDE JUTRAS-PERREAULT

Institute: NMBU
Position: Post-doctoral fellow
Project period: 2023-2026
Topic: Remote sensing and Forest information

The primary objective of this project is to improve tools and develope methods for achieving a more objective and accurate mapping of environmental data relevant to certification, both pre- and post-harvest. Thus far, my efforts have been concentrated on detecting and classifying retention trees post-harvest, using airborne laser scanning data and aerial imagery, to provide an assessment of retention tree volume at the stand level.

insights into using the direct method for site index prediction in forest management.

Tollef Tinholt Låg

Remote sensing as a tool in mapping geological landforms in forests. NMBU.

Låg aimed to streamline forest habitat mapping using QGIS models to distinguish geological landforms from forest landscapes. Models were created to identify stream gorges and rock walls in a sample area in Viken, Norway.

The rock wall model had a 95% success rate, while the stream gorge model had a 45% success rate. This work demonstrates the potential of QGIS tools in efficient and accurate forest habitat mapping, suggesting further research could enhance accuracy.

Communication and dissemination

SmartForest outreach

Partner Visits: A Key to Success

In 2023, SmartForest continued its work towards revolutionizing the forest sector through digital transformation and the application of deep learning and AI. Our collaboration with forest owner associations has been instrumental in driving this change. Some of the year's highlights were our visits to Glommen Mjøsen Skog and AT Skog, where we had the opportunity to discuss and observe forest operations firsthand. These visits provided invaluable insights into the practical aspects of forest management, which are crucial for our research.

Our team had the chance to interact with forest managers, which allowed us to understand the challenges and needs of those working with the practical aspects of forest operation and forest management, thereby enabling us to tailor our research to address these issues effectively.

Our collaboration with the Forest owner associations extends beyond site visits. Their input has been vital in shaping our research agenda, particularly in the areas of logistics and data flow. The goal is to leverage technology to make forestry more efficient and sustainable, while also enhancing profitability.

Partner visit of Simon Berg, Heikki Korpunen, and Stephan Hoffmann from NIBIO at Glommen Mjøsen Skog Image: Rannveig Røstad, Glommen Mjøsen Skog

One key outcome we aim to achieve is reducing logistics costs and seasonal variations in timber supply through smart data usage. This will increase the value creation for Norwegian timber and contribute to a more sustainable forest sector.

As we progress, we will continue working closely with our industry partners. Their insights and feedback are invaluable in helping us develop practical solutions that can drive a digital revolution in the Norwegian forest sector.

Digitalization Forum

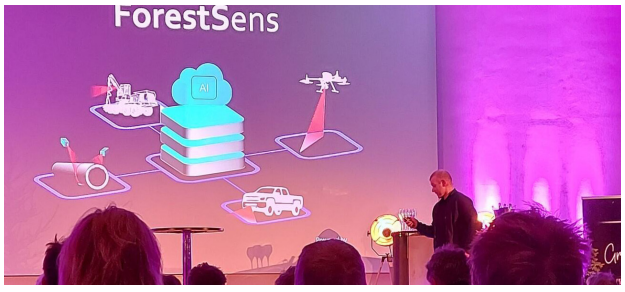
In 2023, SmartForest served as a facilitator for discussing the potential benefits of digitalization in the Norwegian forest sector. The digitalization forum, consisting of core members from forest management organizations and wood users, held three annual meetings to identify new opportunities, discuss potential approaches to improve forest management through digitalization and address common solutions and challenges. Other partners with specific competencies and activities were invited to relevant meetings. The themes for these meetings were based on suggestions from participants of the forum, ensuring a comprehensive and inclusive approach to digitalization in the forest sector.

Tømmer og Høggere
Tømmer og Marked
14.– 15.02.2023

Last year, we were actively involved in two events hosted by Viken Skog, both aimed at engaging the Norwegian forest sector: Tømmer & Marked and Tømmer & Høggere. At Tømmer & Marked, we set up an informative stand and engaged with a diverse audience from the forest-based value chain. The conference set the agenda for forest owners, politicians, and the forest industry, providing us with an excellent platform to share our work and interact with an engaged audience. Tømmer & Høggere was specifically tailored for collaborating contractors in forest operations. We presented our work, sparking interest and questions from attendees. The event offered an interesting program with contributions from various industry actors and a presentation of SmartForest.

Both events were well-attended and provided us with valuable opportunities to share our work and engage with professionals from the Norwegian forest sector. These participations align with our commitment to fostering dialogue and collaboration within the forest-based value chain and discussing the digitalization of the Norwegian forest sector.

SmartForest at Tømmer & Market and Tømmer & Høggere. Image: Katrin Zimmer



Seminar series

We have established the SmartForest seminar series to present topics and results from our activities within SmartForest and to have a platform for partners to give insight on topics from a practical viewpoint. The seminars are a meeting point for all centre partners and participants.

Forest Planning Seminar 09.– 10.03.2023

The Faculty of Environmental Sciences and Natural Resource Management at NMBU organized the Forest Planning Seminar at Holmen Fjordhotell, Asker, from March 9–10, 2023. The seminar is usually held every two to four years as a meeting place for everyone working with forest inventory and forest management planning, public administration, research, and other related fields. The seminar in 2023 was arranged as part of SmartForest in collaboration with NIBIO and the forest industry, where much of the work revolves around resource mapping and forest management planning. The two-day seminar hosted 80 participants.

https://www.forestinventory.no/?p=2455&lang=NO

Forest Road 20.04.2023

The seminar on Forest Roads hosted 39 online participants and talks were presented on the importance of forest roads (Dag Skjølaas, Norges Skogeierforbund), the classification of forest roads (Jan Bjerketvedt, NIBIO), as well as a talk on Potholes in the woods (Stephan Hoffmann, NIBIO), focusing on systems and solutions for automated detection of potholes from driving vehicles.

Harvester Positioning Systems 08.06.2023

The seminar on harvester positioning systems was well visited with 38 online participants, and featured presentations on HarvestSens (Csongor Horvath, NIBIO), developments in harvester positioning systems (Lennart Noordermeer, NMBU) and the development and integration of high accuracy positioning in Komatsu Forest harvesters (Mattias Nyström, Komatsu Forest).

Forest Planning Seminar
Image: Hans Ole Ørka

Conferences

Our team members had the privilege of participating in a series of leading conferences in the fields of forest operations, remote sensing, and forest inventory throughout 2023.

These engagements provided us with invaluable opportunities to share our work, learn from global experts, and stay updated with the latest advancements in our field. The knowledge and insights gained from these conferences will undoubtedly contribute to our ongoing tasks and future initiatives.

OUGN2023 – Spring Seminar for Oracle users, Oslo, Norway, 24-25, 2023

Geospatial World Forum 2023, Rotterdam, The Netherlands, May 02-05, 2023

Growth and Yield Innovations Conference 2023, Canmore, Alberta, Canada, June 18–21, 2023

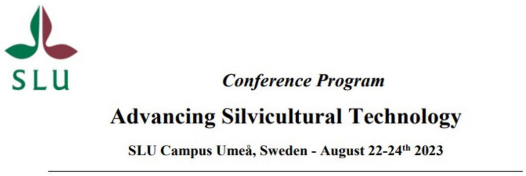
Advancing Silvicultural Technology, Umeå, Sweden, August 22-24, 2023

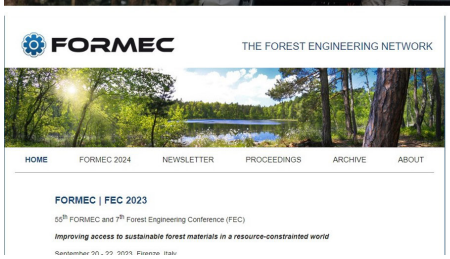
IBFRA Conference, Helsinki, Finland, August 28-31, 2023

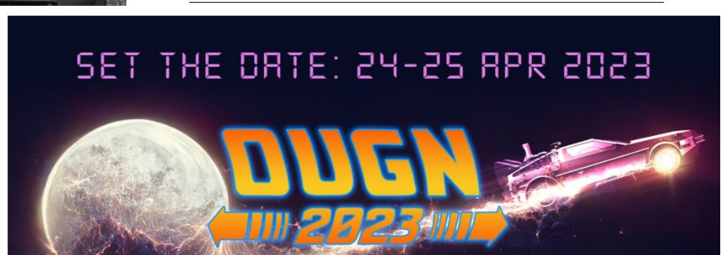
SilviLaser 2023, London, Great Britain, September 06-08, 2023

55th International Symposium on Forest Mechanization (FORMEC) and the 7th Forest Engineering Conference (FEC), Florence, Italy, September 20-24.09, 2023

Annual Mistra Digital Forest meeting, Stockholm, Sweden, November 25, 2023







SmartForest Days

The SmartForest Days 2023 was a lunch-to-lunch event that brought together research and industry partners from SmartForest also including international collaborators. The event was a platform for sharing research findings, discussing innovative ideas, and fostering collaboration.

Day one was filled with presentations showcasing the work within SmartForest. Highlights included presentations on image matching in forest management planning, further development of site index estimation with airborne laser scanning data, semantic and instance segmentation of high-density point clouds, product-adapted quality sorting of timber in sawmills, and damage evaluation in forestry after a storm or snow damage. The day concluded with a presentation on using deep learning models for automating tasks within log measurement and a discussion on innovations and reporting processes within the centre.

The educational component of SmartForest was emphasized through presentations of educational activities, PhD students, and postdoctoral researchers within SmartForest, led by Terje Gobakken from NMBU. Day two focused on environmental considerations and retention trees. Discussions revolved around certification and environmental information, retention trees, and data sharing. The event concluded with four brainstorming sessions on sector-relevant topics: operational technology and infrastructure in the spotlight of "just-in-time" delivery, precision forestry, certification and environmental documentation, and environmental information.

SmartForest Days at Samfunnet in Ås.
Images: Lars Dalen, Stefano Puliti, Katrin Zimmer

Within Centre communication

SmartForest Team meeting

Within SmartForest, we regularly arrange a physical meeting with all UiO, NMBU and NIBIO researchers. These meetings aim to present ongoing and discuss planned work, create an interactive team and workplace, as well as we plan the next year's tasks and activities taking place in SmartForest. The team meeting in 2023 was arranged on May 3rd.

SmartForest Team meeting at NIBIO, Ås on May 3rd.
Image: Katrin Zimmer

Work package leader meetings

Alongside our regular team meetings for researchers, we have established a series of monthly meetings that convene the Work Package (WP) leaders. These sessions are dedicated to reviewing progress and ongoing activities within each WP, facilitating a cohesive approach to our collective research objectives.

Task leader meetings

To enhance the integration of our efforts, several times a year, we expand these discussions to include task leaders, ensuring that the strategic vision and operational tactics are fully aligned across all levels of project execution.

These meetings are instrumental in maintaining a steady stream of communication between the various work tasks, allowing for real-time updates on work progress and immediate identification of any challenges or bottlenecks. Doing so creates an environment where information is exchanged and synthesised, enabling us to adjust our strategies proactively and ensure that all team members are synchronized in their efforts.

SmartForest Lunches

In alignment with our commitment to fostering a collaborative environment and bolstering team dynamics, our centre has instituted a program of monthly communal lunches. This initiative is designed to strengthen our collective identity and nurture the inter-personal relationships among our researchers.

Recognizing that informal gatherings are a bedrock for spontaneous idea exchange and innovation, these luncheons serve as a catalyst for cross-disciplinary dialogue and open channels of communication. Moreover, they facilitate a seamless flow of information, ensuring that all team members are abreast of the latest developments and collaborative opportunities.

PhD and Post Doc lunch

Throughout 2023, SmartForest held monthly lunches for our PhD candidates and PostDoc fellows. These gatherings were more than just social events; they served as a dynamic platform for our young researchers to engage in intellectual exchange, discuss methodologies, share their findings, and tackle challenges together.

Such meetings are incredibly advantageous as they foster networking and collaboration opportunities. They also contribute to building a sense of community within SmartForest, which is crucial for cultivating a positive and supportive research environment.

Social media

In our ongoing efforts to engage with our community and stakeholders, we have been actively using LinkedIn and X, to share updates, insights, and relevant content. Here, we present the key metrics from our social media activities over the past year.

SmartForest4.0

- 967 followers
- 49 original posts
- 1199 reactions
- 50408 organic impressions

SmartForest_SFI

- 1193 followers
- 26 original tweets
- 196 reactions
- 16760 organic impressions

Our LinkedIn page SmartForest4.0 has proven to be an effective platform for professional networking and sharing in-depth content about our Centre for Research-based Innovation. Over the past year, we have experienced a growth in our LinkedIn follower count, soaring from 541 to 967 followers, representing an increase of approximately 79%. This indicates increased interest and engagement from our professional community in our research and innovation activities.

Webpage

The webpage of SmartForest is smartforest.no.

SmartForest in media 2023

Forskere fra SmartForest på besøk hos Glommen Mjøsen Skog – Glommen Mjøsen Skog, 14.09.2023

Sammen for et stadig smartere skogbruk – Glommen Mjøsen Skog, 13.09.2023

Nytt posisjoneringssystem på hogstmaskin – norskskogbruk.no, 15.05.2023

Wood belongs to circulation. How not to waste the Czech resource is solved by a new INCIEN study (in Czech) – zajimej.se, 26.04.2023

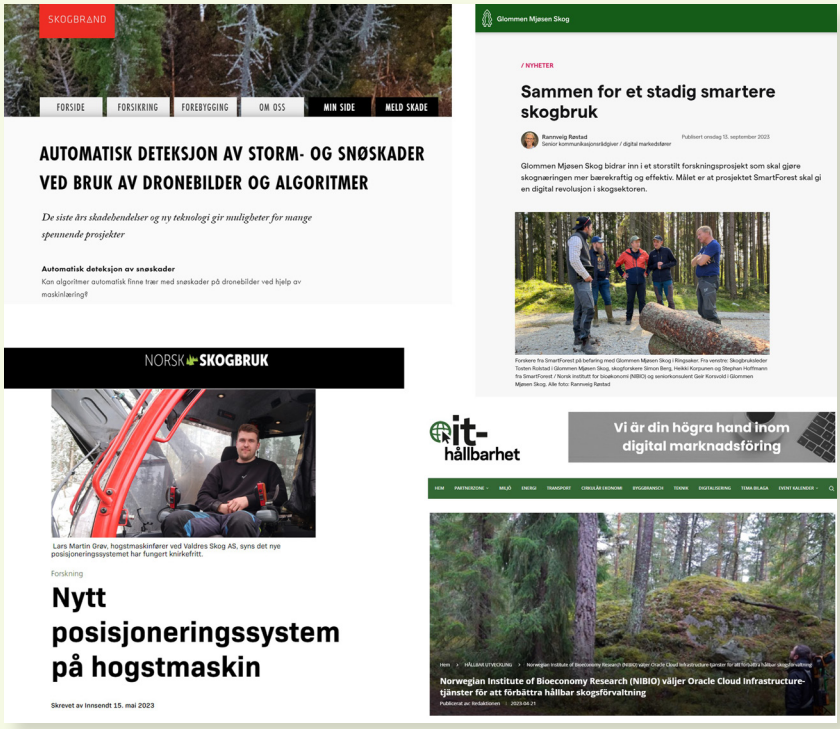
Artificial intelligence at the service of forests (in Spanish) – sevilla.abc.es, 24.04.2023

Dansker vil redde skovene med cloud teknologi – computerworld.dk, 21.04.2023

Norwegian Institute of Bioeconomy Research (NIBIO) väljer ORACLE Cloud infrastructure-tjänester för att förbättra hållbar skogsforvaltning – it-hallbarhet.se, 21.04.2023

Norges skoger skal reddes av KI, Cloud og droner – cw.no, 20.04.2023

NIBIO velger Oracle Cloud Infrastructure-tjenester for å forbedre bærekraftig skogforvaltning – oracle.com, 13.04.202



Automatisk deteksjon av storm- og snøskader ved bruk av dronebilder og algoritmer (in Norwegian) – skogbrand.no, 13.04.2023

Trimble Technology Lab established at University of British Columbia for its Faculty of Forestry – geoweeknews.com, 06.03.2023

How to use the potential of wood? A new INCIEN think tank study will focus on the potential of the circular economy in the Czech forestry and wood processing industry (in Czech) – incien.org, zajimej.se, 11.01.2023

Czech forestry, wood processing industry and circular economy: how to better use the potential of wood? (in Czech) – feedit.cz, 11.01.2023

Das SmartForest-Projekt arbeitet daran, mit Hilfe von Digitalisierung die Waldwirtschaft in Norwegen zu verbessern (in German) – Weltvermesserer, 11.01.2023

Publications

Scientific publications

Hoseini, M., Puliti, S., Hoffmann, S., Astrup, R. (2023). Pothole detection in the woods: a deep learning approach for forest road surface monitoring with dashcams. International Journal of Forest Engineering

https://doi.org/10.1080/14942119.2023.2290795

Noordermeer, L., Ørka, H.O., Gobakken, T. (2023). Imputing stem frequency distributions using harvester and airborne laser scanner data: a comparison of inventory approaches. Silva Fennica, 57:3, article id 23023

https://doi.org/10.14214/sf.23023.

Noordermeer, L., Korpunen, H., Berg, S., Gobakken, T., Astrup, R. (2023). Economic losses caused by butt rot in Norway spruce trees in Norway. Scandinavian Journal of Forest Research, 38:7-8, 497-505

https://doi.org/10.1080/02827581.2023.2273252.

Straker, A., Puliti, S., Breidenbach, J., Kleinn, C., Pearse, G., Astrup, R., Magdon, P. (2023). Instance segmentation of individual tree crowns with YOLOv5: A comparison of approaches using the ForInstance benchmark LiDAR dataset. ISPRS Open Journal of Photogrammetry and Remote Sensing

https://doi.org/10.1016/j.ophoto.2023.100045.

Hansen, E., Rahlf, J., Astrup, R., Gobakken, T. (2023). Taper, volume, and bark thickness models for spruce, pine, and birch in Norway. Scandinavian Journal of Forest Research, 38:6, 413-428

https://doi.org/10.1080/02827581.2023.2243821.

Wielgosz, M., Puliti, S., Wilkes, P., Astrup, R. (2023). Point2Tree(P2T)—Framework for Parameter Tuning of Semantic and Instance Segmentation Used with Mobile Laser Scanning Data in Coniferous Forest. Remote Sensing, 15(15), 3737

https://doi.org/10.3390/rs15153737.

Moan, M.Å., Noordermeer, L., White, J.C., Coops, N.C., Bollandsås, O.M. (2023). Detecting and excluding disturbed forest areas improves site index determination using bitemporal airborne laser scanner data. Forestry: An International Journal of Forest Research, 2023; cpad025

https://doi.org/10.1093/forestry/cpad025.

Conference contribution, workshops and seminars

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Gobakken, T., Rahlf, J., Hansen, E. (2023). Nye volum- og avsmalningsfunksjoner. Takst- og planseminar 2023, Holmen Fjordhotell, Norway, March 09-10, 2023

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Methods and datasets

taperNOR (2023): Taper models for spruce, pine and birch in Norway and helper functions.

https://github.com/SmartForest-no/taperNOR

Point2tree (2023): Instance and semantic segmentation of dense laser scanning point clouds from terrestrial platforms (TLS/MLS).

https://github.com/SmartForest-no/Point2tree

FOR-instance (2023): FOR-instance: a UAV laser scanning benchmark dataset for semantic and instance segmentation of individual trees

https://zenodo.org/records/828779, https://doi.org/10.48550/arXiv.2309.01279

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Johannes Breidenbach	NIBIO	Remote sensing and Forest information
Carolin Fischer	NIBIO	Wood Quality
Kjersti Holt Hansen	NIBIO	Precision Silviculture
Marius Hauglin	NIBIO	Remote sensing and forest operation
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Csongor Horvath	NIBIO	Sensors and Robotics
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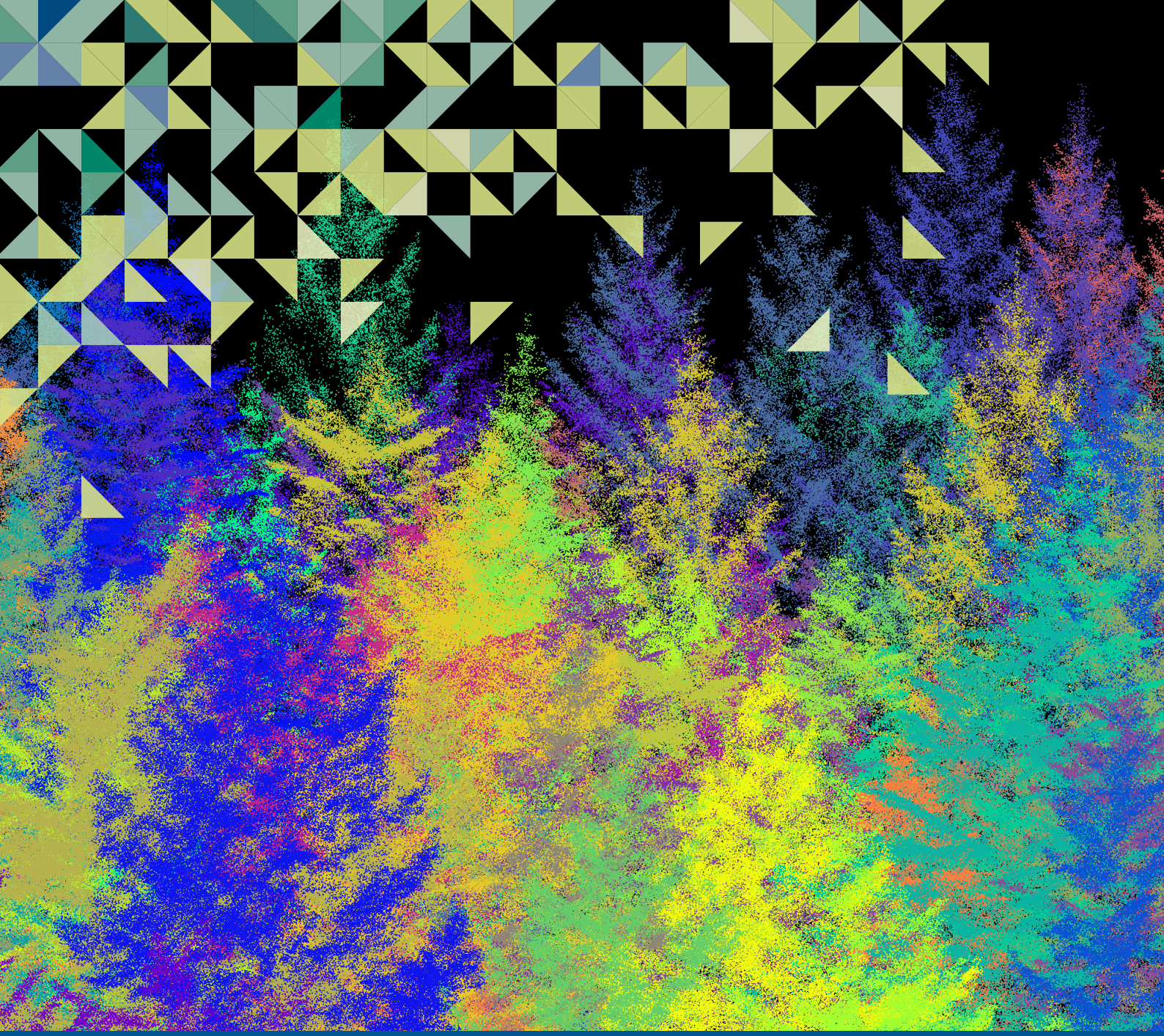
Photo:

Accounts

FUNDING	Amount (NOK)
Research Council	15 363 000
Host Institution (NIBIO)	4 801 000
Research Partners	4 786 000
Industry partners	5 384 000
Sum	30 334 000

COST	Amount (NOK)
Host Institution (NIBIO)	15 823 000
Research Partners	11 627 000
Industry partners	2 884 000
Sum	30 334 000

Photo:



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