SMARTForest

Bringing Industry 4.0 to the Norwegian forest sector

Annual Report 2022

Contents

Front cover photo: Anette Tjomsland Spilling

Summary

The SmartForest team from research and industry in September 2022 gathered during the first day of the SmartForest Days. Photo: Lars Sandved Dalen

For SmartForest, 2022 was a blooming year full of activities, data collection, collaboration amongst partners, and innovation creation. 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. SFI SmartForest aims 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. The first innovations (i.e. ForestSense) resulting from the centre are now being tested by the industry partners.
- The SmartForest team works intensively on knowledge dissemination, and we were busy participating in conferences, seminars, fairs and partner events. We actively share our activities on our project webpage and on social media. Follow us!
- In 2022, we expanded our team and hired two Postdocs and three PhD candidates.
- A large number of students were involved in field campaigns for data collection last summer.
- We had our first internal conference "SmartForest days" happening in September 2022, a two-day event with over 60 participants from all partners. We presented ongoing work and first results, had hands-on workshops to try some of our developed tools, and a field trip with stations on forest management, drones, forest roads and digital twinning.

We are looking forward to a new exciting year in SmartForest, and we believe that 2023 will be the next leap for output of both scientific production and innovation creation. All partners have great ambitions for applying technology and innovative solution to support sustainable forest management in Norway. We believe that intensive collaboration between research and industry is decisive for the success of the centre and the development of a strong Forest-tech sector in Norway!

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, increased production efficiency, improved environmental efficiency, and overall increased 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 will have defined tasks which will be 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

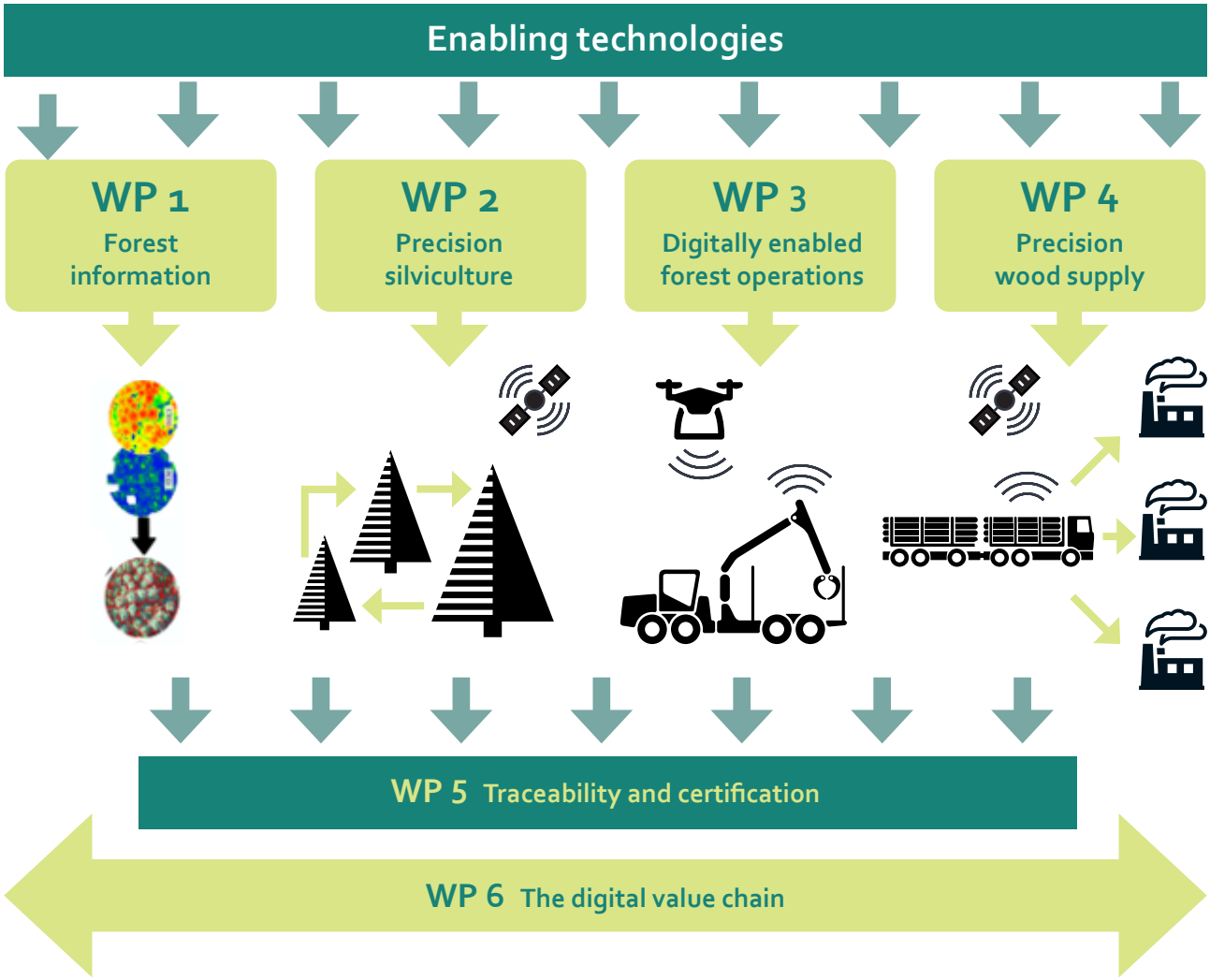
Erik Næsset is a professor in remote sensing and forest inventory at the Norwegian University of Life Sciences (NMBU), Faculty of Environmental Sciences and Natural Resource Management, in Ås, Norway. Næsset's research focuses on the use of remote sensing and other geospatial technologies for forest 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 Health and Ecology, 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 the development of 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 costs of logistics, reduce seasonal fluctuations in wood supply, and increase the value creation of the harvested wood. Through the application of emerging technologies precision wood supply can be optimized, in a way that supply, and demand are matched both with respect to time and quality.

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 as well as 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 by development of a series of application 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 the use of remote sensing technologies for forest monitoring and management planning.

Photo: Lennart Noordermeer

Organisation

Organisational structure

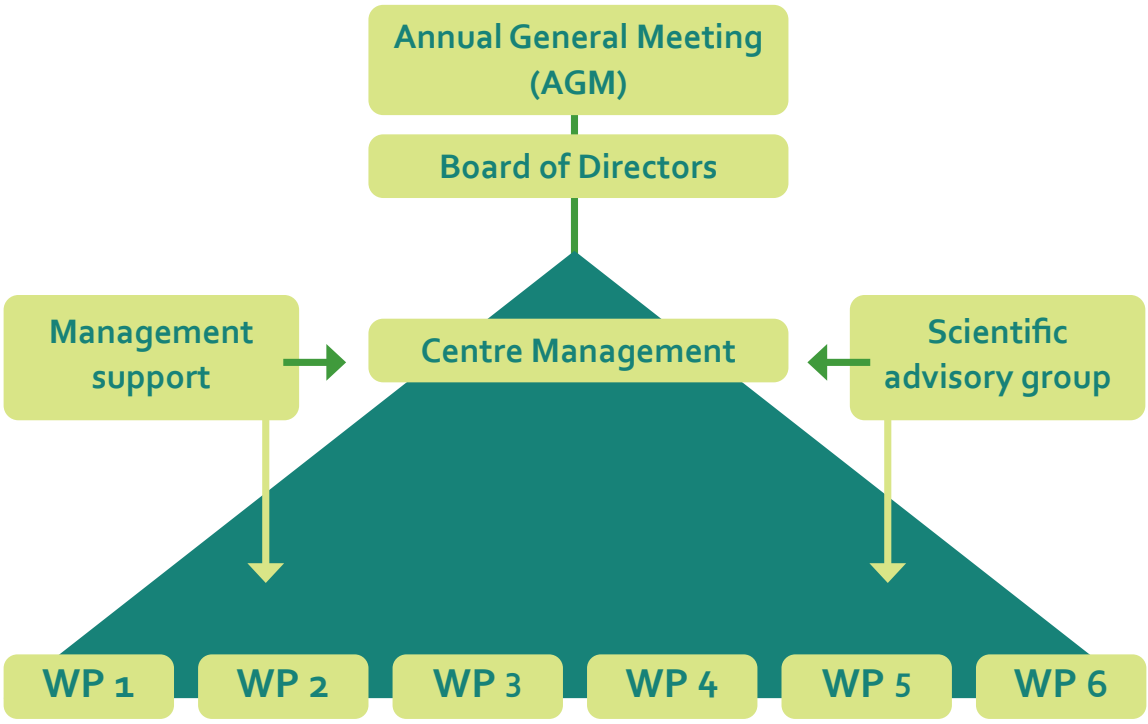
The Annual General Meeting convenes once a year to discuss the Centre's activities, present result highlights from the past year and discuss forthcoming plans. The board is the ultimate decision-making body of the consortium. The scientific advisory group ensures the centre's excellence.

In collaboration with the work package leaders, the following experts were invited to the SmartForest scientific advisory group:

Juha Hyppa, Prof. Adj. Prof. D.Sc. (Tech.), Head of the Department of Remote Sensing and Photogrammetry at the National Land Survey of Finland (NLS), Finland.

Bruce Talbot, Professor of Forest Operations at Stellenbosch University, South Africa.

Franka Brüchert, PhD, Deputy Head Department of Forest Utilisation with a focus on wood technology at FVA, the Forest Research Institute Baden-Württemberg, Germany



Board Members 2021–2023


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
Erik Trømborg, Professor 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

Centre Communication

Katrin Zimmer, NIBIO

Administrative Support

Kristian Fæste, NIBIO

Eva A. Haugen Johnson, 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 will be responsible for identifying bottlenecks or areas needing R&D focus and implementing 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) will be responsible for a large part of the communications activities targeted at the sector as well as towards the policy system.

Machine manufactures and contractors

Komatsu Forest will support the project with access to machine data which is a key enabling technology applied heavily both in the forest information WP as well as in the digital operations WP. Komatsu Forest will support integrating new sensor and automation systems in actual operational forest machinery but also allow 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 of developing the digital value chain by making the existing machine data system SilviSmart into a central part of the digital value chain as well as to test and evaluate 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 will participate 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 will participate in developing and implementing the digital value chain. Skogdata will be central for getting access to existing data streams but also to implementing innovation in the digital value chain. **Norsk Virkesmåling**, the organization responsible for the measurement of harvested timber, will participate actively with the ambition of completely revolutionizing how timber is measured (volume and quality) in Norway. **Skogbrand** is the only insurance company specializing in forests in Norway and will focus on utilizing continually updated forest information obtained through remote sensing and drones to better assess damages for insurance payments and as utilization of the generated data to better estimate risk. **Biodrone** is specialized in drone services within the forestry and agricultural industry. Within SmartForest, they will participate by data capture of drone laser data. **Ard Innovation** contributes to increased value creation based on research, innovation and expertise and will carry out innovation management for the centre.

Sawmilling industry

Moelven Virke will represent the timber buyers and mills in SmartForest. Moelven Virke will play 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 as well as product breakdown of the individual logs. Further, Moelven will be 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 will be represented by the **Norwegian Agriculture Agency (NAA)**, who will participate through development of 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 with researchers from the newly established **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 on 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 have included 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 Swedish **Mistra Digital Forest** program collaborates with focus on topics related to improved forest information as well as traceability from the forest and through the mill and how to use this information for increased value production.

2. The **Forestry 4.0** initiative by Canadian **FPInnovations**, cooperates with focus on digitally enabled forest operations as well as on automation of forest operations.

3. The virtual forest project established by the robotics department of German **RIF Institute for Research and Transfer e.V.**, corporates with focus on digital twinning in forestry, and the design and implementation of industrial sensors in forestry.

All three international partners are committed to facilitating researcher exchange and co-organization of meetings and workshops. This will ensure that the SmartForest researchers and industry partners involved in the project,quickly advance and stay at the forefront of research. Further, the international partners will contribute with key competencies in selected R&D activities that will 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

RIF Institut für Forschung und Transfer

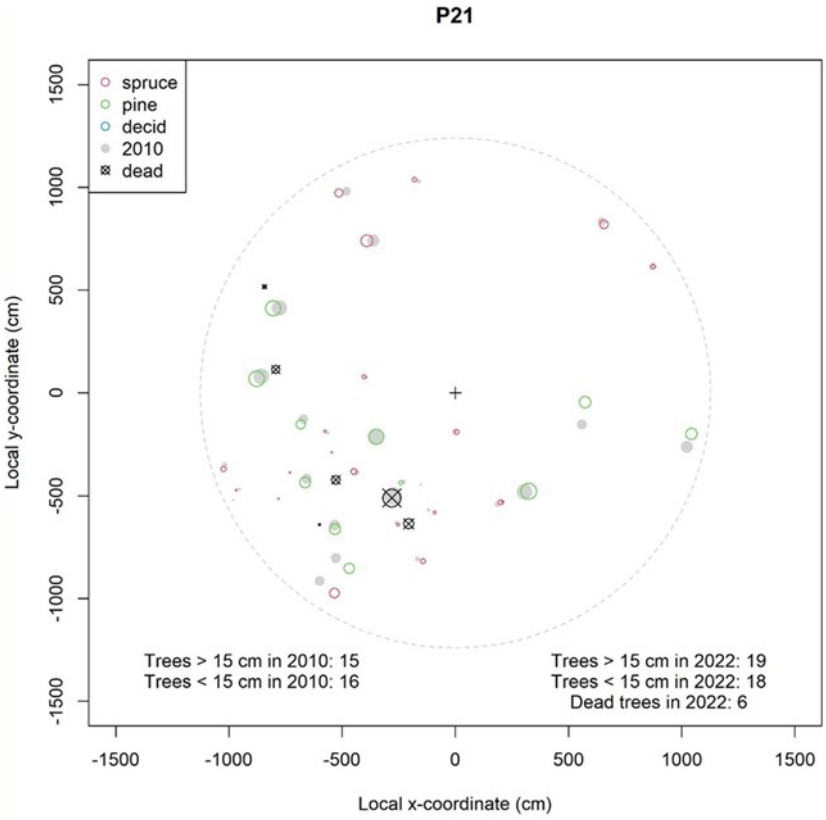
Scientific activities and results

Field campaign in Våler (WP1)

During the summer and fall of 2022, an extensive fieldwork was conducted in an 850-hectare forest study area located in Våler municipality, south of Ås. Temporally consistent remotely sensed data were collected by the SmartForest partner, Field Group. The fieldwork involved remeasuring (compare figure WP1-1) the diameters and heights of trees in 1,102 sample plots that had previously been measured in 1998, 1999, and 2010. The study area was comprised of 178 large plots (400 m^2) distributed systematically across the entire area, as well as 924 smaller plots (250 m^2) located within selected stands.

WP1-2. Part of the NMBU crew for the fieldwork in Våler.

Approximately 15 field workers (WP1-2) were employed between May 24th and November 24th, measuring the diameter of more than 33,000 trees and almost 4,000 tree heights. This dataset will be a critical component in studies of the usefulness of data assimilation techniques for improving estimates of forest resources. The dataset will also be used in other SmartForest work packages and tasks.

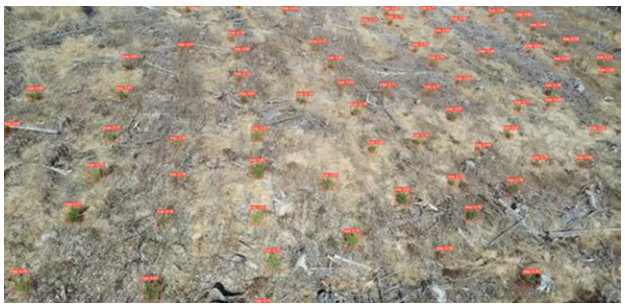


WP1-1. Illustration of measurement and remeasure-ment of a 400 m^2 field plot (plot #21 of a total of 178 plots). Coloured circles (see legend) mark the position of trees measured in 2022 and light grey circles mark positions of trees registered in 2010. The displacements between grey and coloured circles representing trees that obviously are the same, are due to random errors on angle and distance measurements for the two years. The sizes of the circles are proportional to the respective diameters at breast height.

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

Young stand tending (WP2)

One of the most important measures in silviculture is to secure successful regeneration after cutting. If the forest is to keep providing us with quality timber and high carbon sequestration, good seedling establishment after harvesting is a prerequisite, and accurate assessment of regeneration success is needed. Today, controls of planted or naturally regenerated stands are done manually, usually by forest owners' associations or by forest officers. Using drones for assessment could decrease time use and costs, making it possible to control a larger number of stands with much higher accuracy.



WP2-1 Seedlings detected by the deep learning algor-thm in one of the field trials.
Drone image: Stefano Puliti

We wanted to test regeneration control using drone images and deep learning. In 2022, three field trials were established in cooperation with Glommen Mjøsen Skog. The stands were planted 1-3 years ago. Drone images were collected from the stands at different times during spring and early summer, and a first iteration of a deep learning model was developed. The preliminary results imply that detecting seedlings with high accuracy is possible. Seedling size was important for the outcome and doing the assessment three years after planting yielded the best results.

WP2-2 Drones have many applications in forestry.
Photo: Kjersti Holt Hanssen

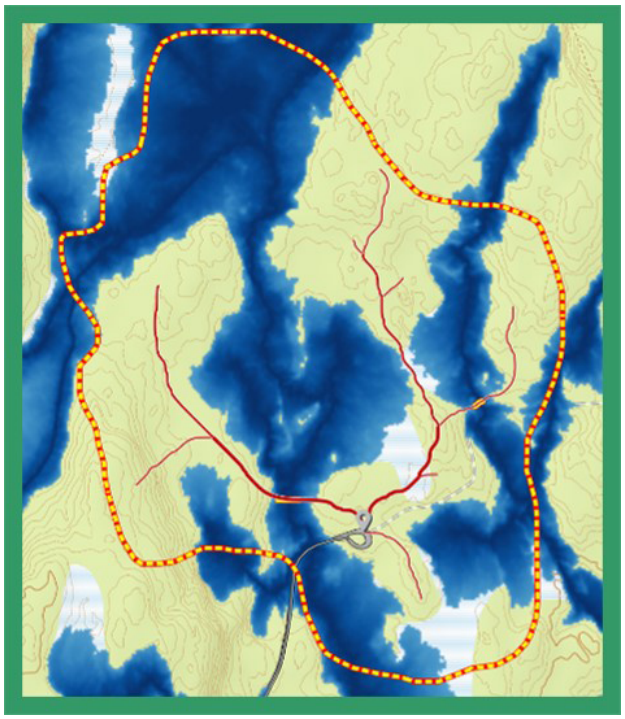
We will continue working on this topic in 2023, collecting drone data in three-year-old stands with varying degrees of "difficulty" (weeds, terrain surface), and improving the deep learning model. The algorithm for regeneration control will then be implemented in DroneSens.

WP2-3 Stefano establishing field trial in Hobøl.
Photo: Kjersti Holt Hanssen

Photo: iStock

Timbertrail in Norwegian conditions (WP3)

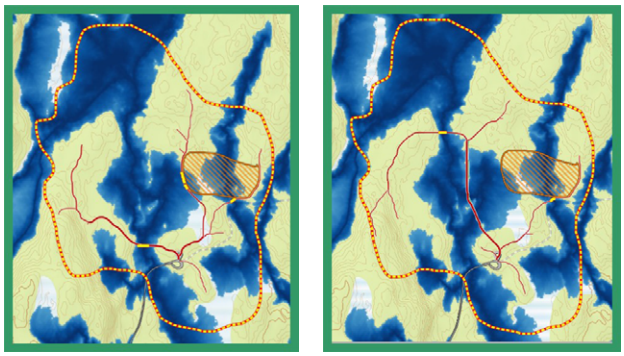
Harvesting operations cause track rutting and CO_2 emissions, and one key aims of the work package on "Digitally-Enabled Forest Operations" is to create and organise digital tools for reducing them. Timbertrail is an application that provides decision support when planning base roads for the forwarding. Timbertrail is a development by Creative Optimization Sweden AB based on Skogforsk's Bestway project. The application considers depth to water, inclination and volume distribution at the sites when suggesting base roads that should be effective with low risk for rutting considering the site conditions (compare WP3-1). Timbertrail is currently in use for decision support during planning in Sweden and Finland and could potentially be used in Norway.



WP3-1 Base roads suggested by Timbertrail based on depth to water, inclination, and volume.

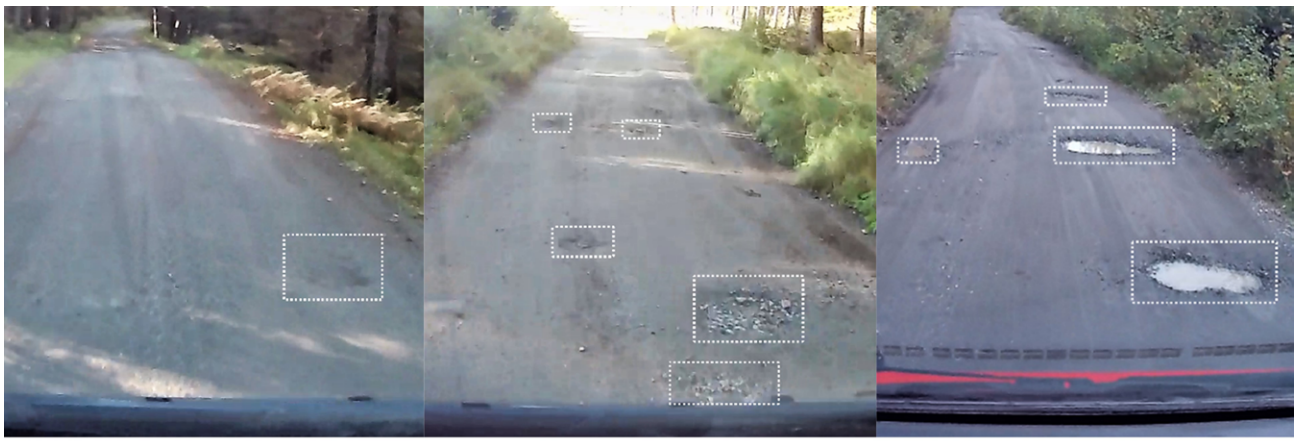
Timbertrail was tested by four planners located in different areas in Norway, representing both western and eastern Norway, to see if it works in Norwegian conditions. In short, Timbertrail did not work well in western Norway while it did work in eastern Norway at normal and easy sites. At difficult sites there were differing opinions whether Timbertrail worked well in eastern Norway. In conclusion, Timbertrail could probably work well in a relatively large area of Norway.

Based on the respondents comments a recommended working technique is to use Timbertrail as a guideline and to do changes during the in-field planning. The changes should mostly be minor as for example moving the ruts by a few meters, but could occasionally be larger as adding No-go areas or adding ruts where the forwarder can travel and rerunning the optimisation (compare WP3-2).



WP3-2 left: effects of adding a No-go area to the site. WP3-2 right: effects of adding a route where the forwarder can drive.

There has been and is an ongoing development of Timbertrail by Creative Optimization and also of the publicly available indata by NIBIO. Currently, one of the forest owner's associations partners in SmartForest is testing an improved version of Timbertrail as an integrated part of their planning system.



(a) (b) (c)

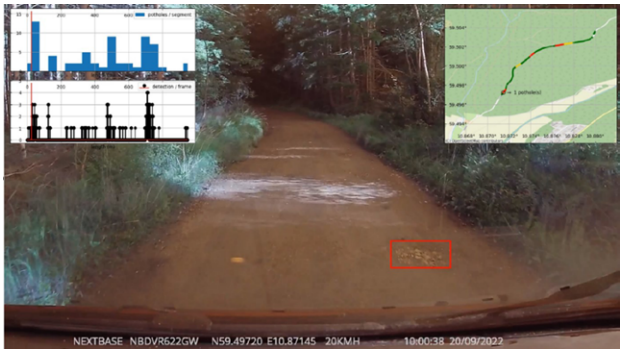
WP4-1 Exemplary pothole conditions used to train the detection model: (a) light roadway depression (dry conditions) in the wearing course, (b) deep pothole with dispersed aggregates of the base layer, and (c) waterfilled potholes. Photo: Stephan Hoffmann

Potholes in the Woods (WP4)

Forest roads are a central part of the forest infrastructure to implement any value chain. But forest roads are also subject to wear, and a deterioration of the network will limit its functions, reduce traffic safety, and increase the threat to road induced environmental problems. Thus, a constant monitoring of the forest road network condition is essential for scheduling required maintenance works in time and to avoid cost intensive repairs. Indeed, managing a forest road network in a sustainable manner is one of the major challenges for forest owners and efficient digital solutions to substitute on laborious, manual road monitoring are lacking in the forest sector.

The SmartForest team developed an economic approach to detect potholes as an obvious indicator for a road's maintenance need. GNSS referenced dashcam footage from a moving vehicle was used to train a model through an object detection algorithm on various grades of potholes during different light conditions on forest roads (WP4-1).

Since a GNSS dashcam allocates geographic coordinates to the videoframes, the detected potholes can be allocated a location reference, allowing to count potholes and to generate heatmaps (WP4-2). This is the base for a simple, but efficient monitoring of the road by identifying road stretches of various maintenance needs according to the frequency of pothole occurrences. This approach allows a high level of customization, with individual creation of damage classes according to road segment length and number of potholes. Therefore, the system can be easily adapted to different road classes or design traffic needs.



WP4-2 Experimental layout for the dashcam based road monitoring system, including a counter of potholes per road stretch and the corresponding heat map (three deterioration classes; green – no maintenance required, yellow – maintenance should be scheduled, red – maintenance is overdue). Photo: Stephan Hoffmann

Although potholes are the most obvious sign of road deterioration for the driver, it is not the only one. Thus, the project team aims to further develop the system and to include other maintenance features such as vegetation on the roadway, wheel ruts, uprising stones, and washboards.

LogsCom – Traceability (WP5)

Tracing logs along the forest value chain is a coveted goal within the forest industry. The possibility to trace logs from the forest to the sawmill does not only provide benefits for certification purposes but also allows a more efficient utilization of a highly demanded but limited resource with simultaneously increasing its value.

Within WP 5 Certification and Traceability we are working intensively with the identification of individual tree logs throughout the wood procurement chain including the collection and connection of log affiliated data on tree and log level. The aim is to make those data available for a more efficient production, utilization and distribution of the resource according to its characteristics.

In November 2022 we started our first trial for traceability of logs using a Logscom marking system in the harvester of Solør Vgs. Avd. Sønsterud. In collaboration with WP6 we created a demo field trial where we mark sawlogs with a unique code spray-painted on individual log level and connect data from drone scanning, the HarvestSens (WP3), a sensor and positioning solution installed on the harvester cabin, and the stemfiles produced by the harvester.

The timber is then transported to Moelven Våler where we have a camera solution installed and we aim for an automated reading of the numbering and connecting with the log information of their 3D and X-ray log scanners.

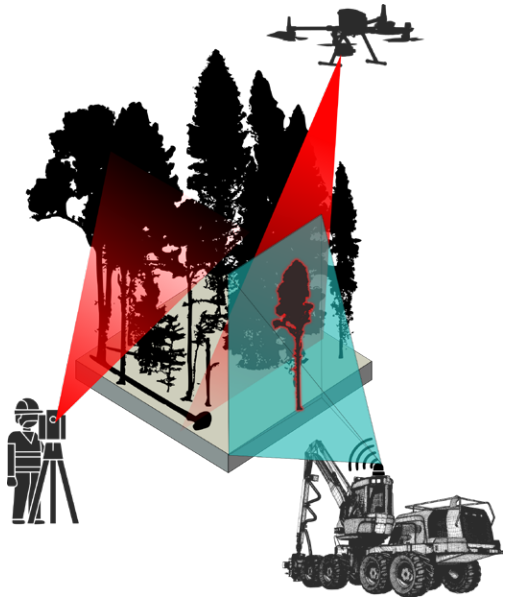
WP 5-2 Camera solution for automated reading of the log ID and connection to the log characteristics from the log scanners at Moelven Våler, view from camera.

In 2023, we are working on the algorithms to improve the automated reading and using stereo cameras to detect log features such as the dimensions of the logs.

WP 5-1 LogsCom log marking system installed in harvester head at Solør VGS avd. Sønsterud. Photo: Carolin Fischer

ForestSens: from proximal sensing to actionable insights with AI and cloud-based processing (WP6)

In SmartForest we have sensors such as camaras or lidars positioned throughout the production chain either at fixed positions such as mills, on machines, on drones, on cars or truck or simply just carried by people working in the field.



WP6-1 Examples of Sensor Data from the Forest Picture: Stefano Puliti

The sensor solutions collect enormous amount of data that must be effectively transformed into information and actionable insight in order to support more production and environmentally efficient forest value chains. To enable the conversion from sensor data to insights we rely on the emerging technologies of AI and cloud computing.

ForestSens is a cloud-based platform that we have built to collect and process sensor information and apply AI algorithms. Results are made readily available through easy to use geospatial standards. ForestSens has a user-friendly interface where the only action you take is to upload your data and select the type of analyses that you wish to carry out. Use of the results from the analysis, will be carried out in existing GIS-based forest management and decision support systems. Hence, ForestSens does not take over the role of existing management or decision support systems but simply enables easy integration of a flow of information from sensor data combined with AI as input to existing systems.

In ForestSens, a “Sens” is the combination of a senor (data) and a family of algorithms designed to analyze the sensor data. We are working on several senses here exemplified by DroneSens, RoadSens, and HarvestSens. DroneSens uses camaras and lidars on drones and algorithms for generating preharvest, postharvest, and forest damage assessment. RoadSens consists of sensors on cars and truck used to access road maintenance needs. HarvestSens used camaras and lidars on forest machines to map harvest progress and monitor environmental impacts.

The ForestSens platform is now being actively tested by SmartForest partners and we hope to use as a key infrastructure in the Centre over the coming years.

WP6-2 ForestSens

Education

Teaching

Through SmartForest, a PhD course on Mixed-effects Models was held at NMBU as a part of the NOVA university network. The course was organized by Hans Ole Ørka and Svetlana Saarela from NMBU and given as a full week course from May 9th to May 13th 2022, in Ås, Norway.

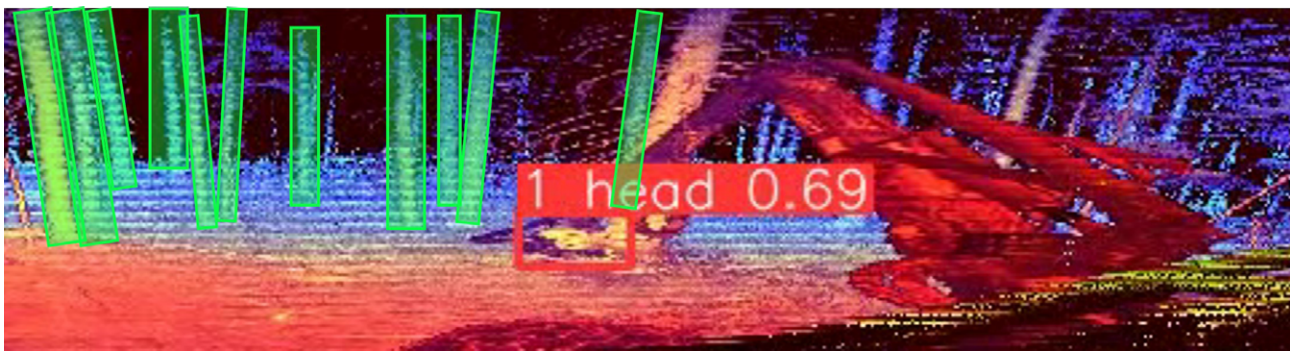
The course covered mixed-effect modelling as an essential tool for modelling based on data with various kinds of grouped structures. Examples include data from clustered sample plots in forest inventories, longitudinal data where observations have been made on the same objects repeatedly, and hierarchical data structures where, e.g., trees on plots are the study objects. Similar data structures are also common in disciplines other than forest inventory. The course introduced the mixed-effect modelling theory starting with a theory on modelling with categorical variables through generalized linear mixed-effect modelling when non-gaussian assumptions are employed. The course was intended for students and researchers in ecology, natural resources, forestry, agriculture, and environmental sciences.

https://www.forestinventory.no/wp-content/uploads/2022/02/220223_MM_for_FA_2022_syllabus.pdf

Phd candidates and Postdocs

During 2022, 5 PhD students and 2 Post-doctoral fellows were working on topics related to the Centre topics, of whom 5 were hired during the year. Unfortunately, one of the PhD candidates, Matthias Göhl, left the position to work elsewhere.

Harvester head detection. Image by Csongor Horvath and Stefano Puliti



Phd candidates and Postdocs

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 working on improving the accuracy and precision of site index estimation with remotely sensed data. So far in the Ph.D. project, I have focused on the classification of areas unsuitable for site index determination due to disturbances and how we might determine the site index when we have time series of remote sensing data.

MATTHIAS GÖHL

Institute: NIBIO
Position: PhD candidate
Project period: 2021–2022
Topic: Obtaining forest road geometric information from remotely sensed data using a deep learning approach.

The forest road network is central for an efficient wood supply but often varies in standard and maintenance status. Here remotely sensed data and truck-based sensors can be applied to map and monitor the current state of the forest road network. We use airborne laser scanning data to determine the correct road geometry (center line location, gradient, and curvature) at selected forest roads in regions with high-
density ALS data availability. Further we use various proximal sensors and AI to identify road deteriorations and quantify the maintenance status of a monitored road stretches.

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

Good decisions require good data, however increasing the data quality comes with a cost, thus its acquisition must be justified.
I explore how to evaluate the value of information with the use of stochastic programming, and how we can incorporate data uncertainty and risk management into the decision process to help to reduce expected losses and assure optimal forest management decisions under any possible future scenario.

YOHANN JACOB SANDVIK

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

My PhD is centred around application of deep learning for automation of tasks in the forestry sector. More specifically, I am working with the application of deep learning through computer vision to perform tasks such as scaling and grading of logs using images, and photogrammetric data.

JAIME CANDELAS BIELZA

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

The main goal of the PhD is to improve operational forest management information using remotely sensed data to support precision forestry with improved accuracy and precision while reducing inventory costs. Improving the accuracy and precision of the forest attribute estimates and quantifying their uncertainties are essential to improve management decisions. Specific objectives include evaluating different methods and data sources (aerial imagery, optical satellites, airborne laser scanning) to provide tree species information at an operational level; characterizing the uncertainty of stand-level forest site-index estimates in Forest Management Inventories, (FMI); and developing a system for location of field sample plots in FMIs in real-time using auxiliary data.

MACIEJ WIELGOSZ

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

The project is about building a set of methods which allow to precisely perform semantic and instance segmentation in the point cloud domain. In practical terms, it means that once a point cloud is provided the software can assign each point to a given class (vegetation, stems etc. and tree instance). Consequently, a user can separate individual trees and this information can be used to calculate a series of useful secondary parameters such as trunk volume etc. An ambition is to create a pipeline which works for a broad set of forests and can be automatically or semi-automatically updated once new data is provided.

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

I am a member of the sensor development team at SmartForest, where we work on designing and prototyping sensor solutions for digitalization and optimization of various silviculture operations. The sensors are aimed to serve purposes such as constant monitoring of forestry operations, performance assessment, and failure prediction in the infrastructure or production processes. In my recent work I was involved in a forest road monitoring project for generating regularly updated road surface degradation maps in terms of potholes. Currently, I work on a sensor for the quality assessment of logs in sawmills using a deep learning-based computer vision.

PhD and Post Doc lunch

During 2022 SmartForest established a monthly PhD and PostDoc lunch. These meetings serve not only as a social gathering but also as a platform for the PhD candidates and post-doctoral fellows to exchange ideas, discuss methods, share results, and address challenges. These types of gatherings can be very beneficial, as they provide opportunities for networking and collaboration. It can also help to build a sense of community within SmartForest, which can be important for the development of a positive and supportive research culture.

Field campaign with student interns

During the summer months of 2022, we hosted eleven students from The University of Freiburg. During their time at NIBIO their fieldwork focused on the collection of validation data for our research on dynamic Depth-to-Water (DTW) maps for trafficability predictions and digital forest road networks.

Field campaign with students University of Freiburg 2022

Communication and dissemination

SmartForest outreach

Skog og Tre konferansen (June 2nd and 3rd, 2022)

Skog og tre is the annual meeting point for the forestry sector in Norway. In 2022, SmartForest had its own parallel session, presenting the latest news from research and development.

The parallel session of SmartForest (in Norwegian) was well visited and chaired by Rasmus Astrup. Some of the presentations are available online (link on presentation topic).

The Skog og tre SmartForest parallel session had presentations on

- Introduction SmartForest, Rasmus Astrup, NIBIO
- Drones in SmartForest, Stefano Puliti, NIBIO
- Drones for damage evaluation, Kjetil Løge, Skogbrand
- Ambition for the use of drones in Statskog, Kjell Anders Vikan, Statskog
- Tool for optimal bucking, Terje Gobakken and Lennart Noordermeer, NMBU

Skog og tre 2022, parallel session SmartForest

Breakfast seminars at Vitenparken Campus Ås

SmartForest participated on two occasions in the breakfast seminar Series «Fra idé til suksess» of the project «Entreprenørskaps-landsbyen Campus Ås». The project "Entre-prenørskapslandsbyen Campus Ås" is a collaboration between Ard Innovation, Eik Lab, Aggrator and NMBU and funded by Viken fylkeskommune.

August 3rd, 2023. Drones – how can they revolutionize agriculture and forestry

Drones are a versatile tool and have the potential to revolutionize both the agricultural and forestry sectors. The knowledge gained from combining drone photography, sensor data and artificial intelligence can be like magic for productivity of the sectors. (in Norwegian)

The seminar had presentations on

- The Norwegian Center for Drone services, Kjetil B. Mathisen, Norsk senter for dronetjenester
- Drones in agriculture and forestry – what is possible, Atilla Haugen, Biodrone AS
- Drones and deep learning in forestry, the future ahead, Stefano Puliti, NIBIO

November 16th, 2022. There is gold in green forests: Digitalization of Forestry

SmartForest research partners from NIBIO and NMBU and Kjetil Løge from the industry partner Skogbrand Forsikringsselskap talked about research activities, innovations and the utilization of research results in practice (in Norwegian).

The seminar had presentations on

- SFI SmartForest - digitalization of forestry; Rasmus Astrup, NIBIO
- ForestSens – a cloud-based dataplatform for sensordata in forestry; Johannes Rahlf, NIBIO
- New methods for timber measurements, Yohann Jacob Sandvik, NMBU
- Skogbrand – Utilization of data for damage, Kjetil Løge, Skogbrand

Hurdagene September 16th and 17th 2022

Hurdagene is the leading trade fair for operational forestry in Norway. The fair contains exhibitions and demonstrations of machines and equipment for forestry, bioenergy and road maintenance activities.

SmartForest participated the fair with a stand and informed the industry about the ongoing work and vision of the Centre.

Hurdagene 2022, impressions

OracleCloudWorld

In September, Stefano Puliti and Rasmus Astrup, together with Kjell Anders Vikan had two filming days together with Oracle Cloud, who deliver the Cloud solution for the SmartForest AI application ForestSens. The video was premiered at the OracleWorld conference in Las Vegas (October 17–20, 2022) and the video has been available at the SmartForest webpage since. https://smartforest.no/news-and-events/videos/

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 center partners and participants.

Researcher meeting

Twice a year we arrange a physical meeting with all researchers from the UiO, NMBU and NIBIO. The aim of these meetings is to present ongoing work, discuss planned work, to create an interactive team and workplace, as well as we plan the next years tasks and activities taking place in SmartForest. The team meetings in 2022 were arranged on April 28th and October 10th.

SmartForest Team meeting in Vitenparken Campus Ås on April 22nd. Photo: Carolin Fischer

SmartForest Days

We held our first SmartForest conference and gathered participants from industry and research for two days.

Day 1 was held in Vitenparken Campus Ås with presentations from the research side and industry partners. The first part was devoted to the work packages in SmartForest and highlighted the most important research activities and future priorities. The second part concentrated on the needs and issues of some of the business partners. In the afternoon, 3 workshops were set up so everyone could try and experience the possibilities in Timbertrail, ForestSens, and optBuck. It was approximately 65 participants present, and all partners were represented by at least one person. There were also participants from international partners.

SmartForest Days; Impressions of the first day with conference and workshops.
Photo: Katrin Zimmer

Day 2 was held at Oslo Kommuneskog at Bogstad Gård in Sørkedalen. The scheme contained 4 stations in the local area, demonstrating some practical use of some of the results and the work that has been carried out. The topics were:

- Experiences with continuous cover forestry
- Harvest Sens and Digital twin of Oslo Municipality Forests
- RoadSens Trail
- Drone flight and forest registrations

Lively discussions at all the stations and engaging presentations worked well as an arena for professional exchange and for strengthening relations between industry and research.

Feedback from researchers and industry players was that The SmartForest Days had been worthwhile, many exciting things are happening in the Centre, and there are opportunities to produce valuable results over the coming years.

SmartForest Days; Impressions of the second day with field stations in Oslo municipality forests.
Photo: Lars Sandved Dalen and Katrin Zimmer

Publications

Scientific publications

Noordermeer, L., Næsset, E., Gobakken, T. (2022). Effects of harvester positioning errors on merchantable timber volume predicted and estimated from airborne laser scanner data in mature Norway spruce forests. Silva Fennica, 56(1).

https://doi.org/10.14214/sf.10608

Puliti, S., McLean, J.P., Cattaneo, N., Fischer, C., Astrup, R. (2022). Tree height-growth trajectory estimation using uni-temporal UAV laser scanning data and deep learning. *Forestry: An International Journal of Forest Research*.

https://doi.org/10.1093/forestry/cpac026.

Puliti, S.; Astrup, R. (2022). Automatic detection of snow breakage at single tree level using YOLOv5 applied to UAV imagery. International Journal of Applied Earth Observation and Geoinformation. 112, 102946.
https://doi.org/10.1016/j.jag.2022.102946

Lingren, N., Nyström, K., Saarela, S., Olsson H., Ståhl, G. (2022). Importance of calibration for improving the efficiency of data assimilation for predicting forest characteristics. Remote Sensing, *14(18),* 4627.

https://doi.org/10.3390/rs14184627

Master thesis in SmartForest

Godmund Botnevik, 2022, *Assessing the timing of final felling based on saw timber price matrices of Norway spruce (Picea abies) - A case study for Fritzøe Skoger AS* (in Norwegian), Supervisor Lennart Noordermeer, NMBU, https://hdl.handle.net/11250/3029039

Mikal Råheim, 2021, *Use of harvester data as referensedata when mapping totalvolume and sawlogvolume.* (in Norwegian). Supervisor Lennart Noordermeer, NMBU, https://hdl.handle.net/11250/2823097

Social media

LinkedIn (SmartForest4.0)

541 followers (31.12.2022),
322 new followers in 2022

671 reactions to the posts and 29828 impressions until 31.12.2022

29 original posts throughout 2022 (01.01.2022 – 31.12.2022)

Twitter (SmartForest_SFI)

862 followers, 31.12.2022

27 original tweets
(01.01.2022 – 31.12.2022)

259 reactions to the posts, in addition to 62 reposts and 14301 impressions until 31.12.2022

Webpage

The webpage of SmartForest is smartforest.no.

SmartForest i media 2022

08.09.2022

Har gær løst teil å gå her

Solungsavisa – papirutgaven side 8, https://redir.opoint.com/?key=24fITn7G3474HBXeHof4&OpointPDF=true

23.09.2022

Kjell Rune Jonassen får årets inspirasjonspris, Lennart Noordermeer nominert

https://www.nmbu.no/aktuelt/node/46018

03.11.2022

https://www.geoinformatics.com/mobile-lidar-norwegian-forestry/

Mobile LiDAR's role in bringing 'Industry 4.0' to Norwegian forestry

https://www.timberbiz.com.au/geoslam-aims-to-put-norwegian-forestry-at-forefront-of-technology/

GeoSLAM aims to put Norwegian forestry at forefront of technology

https://asmmag.com/products/34953-mobile-lidars-role-in-bringing-industry-4-0-to-norwegian-forestry.html

Mobile LiDAR's role in bringing 'Industry 4.0' to Norwegian forestry

https://eijournal.com/news/products-2/mobile-lidars-role-in-bringing-industry-4-0-to-norwegian-forestry

Mobile LiDAR's role in bringing 'Industry 4.0' to Norwegian forestry

https://www.directionsmag.com/pressrelease/11906

Mobile LiDAR's role in bringing 'Industry 4.0' to Norwegian forestry

https://lidarnews.com/press-releases/mobile-lidar-role-in-norwegian-forestry/

MOBILE LIDAR ROLE IN ... NORWEGIAN FORESTRY

04.11.2022

https://sensorsandsystems.com/mobile-lidar-bringing-industry-4-0-to-norwegian-forestry/

Mobile LiDAR Bringing 'Industry 4.0' to Norwegian Forestry

29.11.2022

https://www.regjeringen.no/no/aktuelt/mote-i-dialogforum-for-skog-og-trenaringen/id2948837/

Møte i Dialogforum for skog og trenæringen

30.11.2022

https://newslanes.com/2022/11/30/norways-answer-to-the-smart-city-is-a-smart-forest/

Norway's Answer to the Smart City is a "Smart Forest"

https://www.geoweeknews.com/news/norway-s-answer-to-the-smart-city-is-a-smart-forest

Norway's Answer to the Smart City is a "Smart Forest"

19.12.2022

https://www.nibio.no/nyheter/kunstig-intelligens-i-skyen-skal-hjelpe-skogsektoren-med-gode-beslutninger?locationfilter=true

Kunstig intelligens i skyen skal hjelpe skogsektoren med gode beslutninger

29.12.2022

https://www.viken.skog.no/aktuelt/artikler/smart-forskning-skal-gi-smartere-skogbruk

Smart forskning skal gi smartere skogbruk

Personell

NAME	I NSTITUTION	MAIN RESEARCH AREA
Rasmus Astrup	NIBIO	Centre Management
Carolin Fischer	NIBIO	Centre Coordination, Wood Quality
Katrin Zimmer	NIBIO	Communications
Stefano Puliti	NIBIO	Remote Sensing and Forest Information
Johannes Rahlf	NIBIO	Remote Sensing and Forest Information
Marius Hauglin	NIBIO	Remote Sensing and Forest Information
Johannes Breidenbach	NIBIO	Remote Sensing and Forest Information
Johannes Schumacher	NIBIO	Remote Sensing and Forest Information
Clara Antón Fernández	NIBIO	Forest Modelling
Kjersti Holt Hanssen	NIBIO	Precision Silviculture
Christian Kuehne	NIBIO	Precision Silviculture
Paul McLean	NIBIO	Precision Silviculture
Simon Berg	NIBIO	Forest Operations and Technology
Heikki Korpunen	NIBIO	Forest Operations and Technology
Helmer Belbo	NIBIO	Forest Operations and Technology
Joachim Heppelmann	NIBIO	Forest Operations and Technology
Jan Bjerketvedt	NIBIO	Forest Roads
Stephan Hoffmann	NIBIO	Forest Roads
Nils Egil Søvde	NIBIO	Forest Roads
Csongor Horvath	NIBIO	Sensors and Robotics
Weria Khaksar	NIBIO	Sensors and Robotics

NAME	INSTITUTION	MAIN RESEARCH AREA
Matthias Göhl	NIBIO	Forest Roads
Maciej Wielgosz	NIBIO	Machine learning
Mostafa Hoseini	NIBIO	Sensor Development
Fride Høistad Schei	NIBIO	Biodiversity
Terje Gobakken	NMBU	Centre Management Remote Sensing and Forest Information
Lennart Noordermeer	NMBU	Remote Sensing and Forest Information
Maria Åsnes Moan	NMBU	Remote Sensing and Forest Information
Hans Ole Ørka	NMBU	Remote Sensing and Forest Information
Marie-Claude Jutras-Perreault	NMBU	Remote Sensing and Forest Information
Bjørn-Eirik Roald	NMBU	Remote Sensing and Forest Information
Jaime Candelas Bielza	NMBU	Remote Sensing and Forest Information
Erik Næsset	NMBU	Forest Inventory and Remote Sensing
Ole Martin Bollandsås	NMBU	Forest Inventory and Modelling
Svetlana Saarela	NMBU	Forest Biometry and Forest Information
Olha Nahorna	NMBU	Forest Biometry and Forest Information
Kyle Eyvindson	NMBU	Forest Management and Optimization
Oliver Tomic	NMBU	Machine Learning
Yohann Jacob Sandvik	NMBU	Timber Measurements
Arnoldo Frigessi	UiO	Statistics/Machine Learning
Manuela Zucknick	UiO	Statistics/Machine Learning

Photo: Shutterstock

Accounts

FUNDING	Amount (NOK)
Research Council	12 174 000
Host Institution (NIBIO)	4 714 000
Research Partners	3 470 000
Industry partners	3 153 000
Sum	23 511 000

COST	Amount (NOK)
Host Institution (NIBIO)	10 867 000
Research Partners	8 731 250
Industry partners	3 647 000
Equipment	265 750
Sum	23 511 000

Photo: Katrin Zimmer

SMARTForest

smartforest.no

Postal address:
SmartForest
Postboks 115
NO-1431 Ås
Norway

Visiting addresse:
SmartForest
Høgskoleveien 8
NO-1431 Ås

Email contacts:
Rasmus Astrup, rasmus.astrup@nibio.no
Terje Gobakken, terje.gobakken@nmbu.no
Carolin Fischer, carolin.fischer@nibio.no