
Mistra
Digital Forest
MISTRA DIGITAL FOREST
2019
Swedish Forest
Industries

VISION & MISSION

The Mistra Digital Forest research program aims to contribute to the transformation of our society to a circular bioeconomy. Specifically, it will contribute to the development of a sustainable forestry sector that utilises digitalisation of the entire value chain. The vision is to create digital solutions for a sustainable and efficient forest-based bioeconomy and the mission is to explore and create enablers for realising a digital forestry value chain.

The research is conducted in four work packages – **Forest facts, Efficient forestry, Forest and forest products values and Coordination and communication.**

Program host is The Swedish Forest Industries Federation and program partners are BillerudKorsnäs, Holmen, SCA, Stora Enso, Sveaskog, Södra, IVL Swedish Environmental Research Institute, KTH Royal Institute of Technology, Skogforsk, Swedish University of Agricultural Sciences (SLU) and Umeå University. The research program is funded by The Swedish Foundation for Strategic Environmental Research – Mistra, and the participating partners.

Read more: www.mistradigitalforest.se

Mistra Digital Forest Annual Report **Design:** Brightnest, 2020

Great digital opportunities for the forestry value chain

The Mistra Digital Forest research program was started in early 2019, getting off to a flying start after a long period of dialogue with all the program participants. The program is well-timed. There is great and growing interest in forest-based issues from a variety of stakeholders, at the same time as there is a rapid evolution of digital tools. Last but not least, the companies which initiated the program and now participate in it, see the great opportunities provided by increased digitalisation in forestry.

The main objective of Mistra Digital Forest is to make an important contribution to the conversion of our society, from a fossil-based economy to a sustainable bioeconomy. We are doing this through the development of both digital technologies and methods for sustainable forestry, and we are delighted with the trust shown by Mistra, which makes this investment possible.

The forest as raw material contains many natural variations. This means that relevant data about the forest has to be high-resolution – which in turn implies a huge amount of data. We currently have both the means and the methods for collecting large amounts of data, for example through laser scanning from the air or the ground. This is supplemented with data from the harvesters and is collected for each harvested tree. New knowledge will lead to greater efficiency and a lower environmental impact.

When I started as Program Director in August 2019, I met a well-planned research program that was already off to a great start. Competent participants from the program office at the Swedish Forest Industries, the six forest companies and the five research providers jointly formulate new research challenges. They all benefit from previously completed projects, and give great strength to Mistra Digital Forest. Interest in the program and an enthusiasm for development has been apparent, not least from the large turnout at the two program conferences we conducted during 2019.

In this report, you will be introduced to a selection of activities that have been initiated in the program. I hope it will give you new insights and thoughts on what opportunities a digital development will bring to the forestry.

Sverker Danielsson
Program Director, Mistra Digital Forest

"Increase digital competence"

One of a total number of four areas of development that forest companies need to address in order to begin a digital transformation is to increase their digital compentence. That is what Jonny Holmström, professor of informatics at Umeå University and the Swedish Center for Digital Innovation (SCDI), states after conducting an interview study among the forest companies.

Jonny Holmström has conducted 16 interviews with people in the forest companies.
– If you want to increase digital opportunities, you have to start by asking people working in the area about the challenges and opportunities that they themselves see, explains Jonny Holmström.
– We note that the raw material-based value chain works efficiently, while the digital value chain is more fragmented, says Jonny Holmström. The volumes of data used in the industry are limited, and mainly related to individual companies.

– We see that there are compartmentalised sectors that need to be addressed. But in reality it is a more complex question. In these companies, there are traditions that have been built up over hundreds of years. The digitalisation of value chains involves higher level of co-operation between organisations, Jonny Holmström explains.

The study also reveals that the level of digital maturity varies.
– Increasing digital competence will promote Swedish forestry in a tangible way. It's not just a question of bottlenecks here and there, instead we see that the entire value chain is affected. But people are aware of this, and there is an enormous urge to take the next step, says Jonny Holmström.

FOUR KEY AREAS OF DEVELOPMENT:

1. **Identify the level of digital maturity**
   We need to know the nature of the problem, and our starting point.
2. **Establish digital ecosystems**
   Digital ecosystems involve moving from a traditional linear value chain to an ecosystem. Data is the key to a functioning ecosystem. The bigger stakeholders may be able to build their own, but there is also potential in a common ecosystem.
3. **Increase the level of service innovation**
   Establish a systematic approach to capturing new service innovations. How do we pick up ideas from our colleagues? How can we build up the different digital services?
4. **Increase digital competence**
   Collaborate with higher education institutions and create tailor-made training for your company. This is fundamentally important and phenomenally exciting! But you have to make demands, and find the right level for negotiations.

First steps for the next generation planning system

In 2009, the Heureka system for forest-based analysis and planning was launched. Karin Öhman is a professor at SLU, and leads the developmental work on forest management planning models based on comprehensive data within Mistra Digital Forest. Throughout the autumn, she has gathered stakeholders to begin work on the next generation planning system.

The Heureka system was developed by SLU (Swedish University of Agricultural Sciences) and Skogforsk. It is an analysis and planning system for Swedish forests.

– We know that the lifetime of this type of system is about 20 years, since the wider world's expectations of forests changes, and knowledge and technology develops. Having said this, it takes at least ten years to develop a new system, so it's high time to start now, says Karin Öhman.

Hopes for the next generation system
During the autumn, two meetings were arranged where representatives of different forest owners, authorities and various forest values contributed their wishes for a future system.

– There is an emphasis that the new system must be able to handle risks, such as fire, storm damage and insect infestation, says Karin Öhman.

This is something currently missing from today's Heureka. The stakeholders would also want a new system to be able to plan for new ecosystem services, as well as facilitating communication.

– We do a lot in forestry, something we must be able to show to customers and to the general public. A system like this could help to point out the future consequences of varying decisions. Different kinds of planning systems increase our ability to act before it is too late. The alternative is to implement management activities out in the forest and then wait and see what happens. But since it often takes a long time, maybe 50–100 years, to see the different consequences, we don't have that luxury. Perhaps by then, the opportunity to shape the landscape as we want it, has already gone, says Karin Öhman.

– Establishing a new research program to develop the new system is our current goal. The parallel development of Heureka will continue, as that system will be in use for many years to come, Karin Öhman concludes.

Increase knowledge to find new business and new strategies

– training is an important step for the management team at Holmen Skog

Today, many companies are taking a huge step forward in a digital transformation that will affect working practices, business transactions, and organisational culture alike. Holmen Skog strongly prioritises finding the right digital strategy for the future. The entire management team is currently being trained, in a venture developed by the Swedish Center for Digital Innovation (SCDI), at Umeå University.

– We have seen that there are different levels of digital transformation. It is not easy to understand the implications for our industry. We used to think that it was all about technology and software, but now we realise that we need to understand the area more broadly, and more deeply, at a strategic level, says Lisa Nilsson, IT Manager at Holmen Skog, a business unit within the Holmen Group.

The training is a proactive initiative where ten people within the management team earmarked their time, in order to increase their knowledge. Lectures are interspersed with workshop sessions, where current issues are incorporated into the theory being presented.

– It is important to understand what this can do for our business. Partly this is understanding the ecosystem of data within which the company operates, and the opportunities that exist for creating even higher values, through co-operation. We often want to do most things ourselves, but in this case, perhaps we need to get used to the idea of collaborating with other stakeholders. Then a strategy is needed so that long term data management is carried out well, says Lisa Nilsson.

Training is part of Holmen's involvement in Mistra Digital Forest, and it is one concrete result of the interview study conducted by SCDI, which shows that knowledge about digitalisation needs to increase within the forest companies.

– Our role is to describe what we see in the research, and based on that to assist the management team in their work of formulating a digital strategy. It is also about promoting digital logic - all of a sudden, different things than before are being seen as resources in the companies. This requires mental restructuring, and that is a process that takes time. This is why the entire management team being involved and committed is so good, says Lars Öbrand, Senior Lecturer of Informatics at Umeå University, who runs the training days.

LISA NILSSON

Photo: Johan Olsson

SCA scanned 50,000 hectares of forest

Last summer, the company Opegieka flew over SCA's forests by Lake Laxsjön in Mid Sweden, and collected data using very high-resolution laser scanning. SCA anticipates that this high-resolution information can be used to make significant improvements in the forestry value chain. There is a great potential to improve the future information flow to the saw mills.

SCA has made the area, which covers 50,000 hectares, available for the Forest Facts study within Mistra Digital Forest.

– Several researchers have been conducting studies in the area using different types of scanning equipment. SLU has scanned parts of the surface with Terrestrial Lidar*, and some areas have been scanned from helicopters. This means that we now have data sets that are describing the area at different levels.

– Now, as we have this "digital test site" we have the basis for ascertaining what we can do with this type of technology in the future, says Magnus Bergman, Chief Technical Officer at SCA.

CLEARLY LINKING THE FOREST WITH INDUSTRY

The 50,000 hectares are located in SCA's core area. The company has forest, sawmills and pulp mills, all within a hundred kilometre radius.

– So far, laser scanning has been used for the rough calculation of volumes. With the help of this new data, with higher resolution, we should be able to identify tree species more clearly and be able to further automate the forestry processes. Furthermore, it should be possible to make earlier forecasts for harvesting, including specifications of the timber that will be delivered to our sawmills, says Magnus Bergman.

In the sawmills, customer orders determine production, and there is always a firm order for the main item being produced.

– If we know early on, which wood properties we can expect to get when we fell a tree, we will be able to be even more explicit towards our internal customers. There is definitely a high potential for improvements and to create value, says Magnus Bergman adding;

– We are not there yet - but we want to evaluate the solutions of the future, now.

MISTRA DIGITAL FOREST TEST SITES

There are five different test sites within the program where high-resolution laser scanning has been carried out. **Mistra Digital Test Sites** are located in different parts of Sweden and hence represents different types of forests. Asa (**1**) (Sveaskog) and Attsjö (**4**) (Södra Research Foundation) are in the south, Siljansfors (**2**) (StoraEnso) and SCA Digital Forest test site (**5**) in mid Sweden, and Krycklan (**3**) (Södra Research Foundation) is in the north of Sweden.

**Terrestrial Lidar is a laser scanning of the forest from an all-terrain machine as a forest machine for example.*

Laser scanning for estimation of tree species and growth

In the summer of 2019, a multispectral laser scanning of forest test sites in Sweden was carried out from the air, within the framework of Mistra Digital Forest in cooperation with the Swedish University of Agricultural Sciences (SLU).

Photo: Opegieka

The dense laser scanning (20 points/m2) allows analysis on single tree level, and the use of two laser colours might improve the possibility to detect tree species. Furthermore, since most of the large areas at the test sites were scanned 2009 as well, it will be possible to study growth down to the level of single trees.

Three of SLU's experimental parks were laser-scanned with a new type of high-resolution laser scanning system, using two-colour laser light. In addition, SCA scanned a 50,000 hectare area outside Sundsvall using the same system, Professor **Håkan Olsson**, at SLU, tells us more about the work.

How did the implementation of Mistra Digital Forest's laser scanning turn out?

– Generally very well, I must say. We were lucky with the weather too!

How does this laser scan differ from other, earlier scans?

– We are testing a scanner that uses two colours of laser light. With the additional information on the amount of reflected laser light in two colours, and not simply the location from where the laser light is reflected, we hope to better distinguish the tree species. We have also scanned at a higher resolution than the National Land Survey's national scan.

– Three of the areas scanned this time – the SLU research parks Asa, Siljansfors and Krycklan – were already scanned ten years ago by SLU's research park organisation. This also makes it possible to investigate how well growth can be measured, using high-resolution laser scanning from two time points. This part of the research is done in the context of the Future Silviculture Program, which is funded by the Wallenberg Foundations. In addition, Future Silviculture and Stora Enso, have also financed the scanning and associated field inventory, while the initial data processing was carried out by the Department of Forest Remote Sensing at SLU.

– The fact that the new national laser scan by Lantmäteriet, the Swedish Mapping, Cadastral and Land Registration Authority, coincides with the program's own higher-resolution scanning provides us with a gold mine, in the form of data. Being able to access their data in parallel with our own is of great benefit to the program, says Håkan Olsson.

How does that benefit the companies within Mistra Digital Forest?

– We hope that access to higher-resolution data with information on both tree species and growth can lead to better planning and decision support for forestry. Since, as a forester, you have access to databases where the forest is described in grid boxes, or as individual trees, you can get better support when determining areas in need for thinning, for example.

– Up to now, forests have been primarily measured using manual methods, which is expensive. In addition, the forest is constantly changing, so for forest data to be useful it has to be updated regularly. Some forest measurements, such as tree height, timber volume and average diameter, can be well estimated already using laser data. With the development being carried out within Mistra Digital Forest, we hope to improve remote estimation of tree species, and growth too. We also get comprehensive forest-based information at tree level as well.

What happens now?

– To begin with, we will calculate models for the height of the ground and the height of the canopy. Another important part of our work package is combining laser data with harvest data. We are very much looking forward to undertaking this exciting work.

Simulation-based design for off-road driving

By simulating machines and terrain, researchers at Umeå University develop knowledge that may support drivers of forest machines, and ultimately for self-driving machines.

Photo: Johan Olsson

Martin Servin works at UMIT Research Lab at Umeå University. He is also co-founder of Algoryx, a university spin-off company in the field of physics-based simulation. Algoryx has expertise in the development of automation solutions for the construction, manufacturing and mining industries, know-how that is now being extended to the development of forest machines within Mistra Digital Forest.

When heavy vehicles are driven in the forest, compaction and shearing can occur at some depth in the ground. This inhibits the formation of roots, and their growth. It can also affect the transport of nutrients and water in the soil.

– This means that growth and the ecosystem in the forest can be negatively affected, resulting in both ecological and financial losses, says Martin Servin. But much is still unknown about how, and when, ground damage occurs and how serious it is.

These are some of the challenges to which researchers want to find a solution. And they use digital terrain and vehicle models to assist them.

– We develop digital solutions so that machines can register the sort of terrain they are in, and how they ought to behave to move efficiently and avoid getting stuck. We also look at what causes damage to the ground, and how that can be avoided. Our goal is that this will result in driver-assistance systems. In the longer term, this can be an important building block for self-driving or remote-controlled vehicles in rough terrain, concludes Martin Servin.

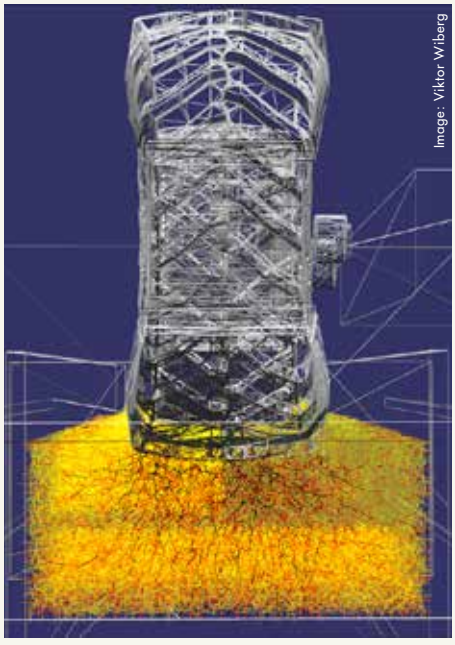


Image: Viktor Wiberg

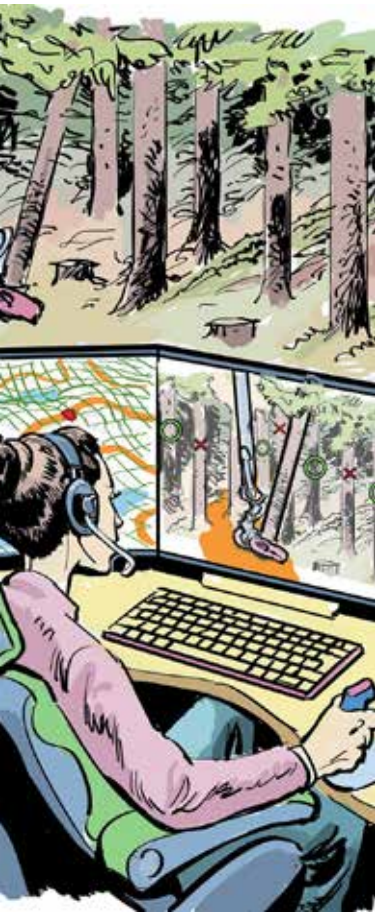
– In the simulation we can study the behaviour of the entire vehicle, and the resulting wheel ruts in the soil. We can also visualise the network of forces in the ground where you drive, and in this way, we can analyse pressure fields and compaction, says Martin Servin.

Image: Skogforsk och Gösta Lindwall

Ola Lindroos, professor at the Swedish University of Agricultural Sciences (SLU), is interested in forest technology, that is the interaction between labour, machinery, forest resources and the environment, all with the aim of ensuring that forestry operations are carried out as efficiently as possible. Creating a new forest machine just because you can, isn't enough. The new machine must make a positive difference – a change that really improves things. So, Ola Lindroos believes that developmental work in forest technology has to be directed towards appropriate solutions.

– It is easy to get drawn into the technological development, but it is important to stop and think, so that investments really do provide genuine, relevant improvements, says Ola Lindroos.

Sweden is a world leader in forest machine technology. But we still have a way to go before we reach full automation. However, there are several driving forces that indicate that development of the processes is moving forwards. Technological development means that the same work can be carried out, but in a better way, while at the same time new products from forest raw materials, and new regulations, affect how forestry work is done – and how it should be.



How will forestry work be done in the future – when will the robots arrive?

Concepts such as robots, digitalisation, AI and big data are generally hot right now – and so are they in forestry. However, this wave reached forestry later than many other industries – why is it like that, and what's the current situation in terms of robots and automation in forestry? Ola Lindroos and his colleagues at SLU discuss this in the chapter "Advances in using robots in forestry operations" in the book *Robotics and automation for improving agriculture*.

"The path to automation is at least as interesting as the goal"

There are several explanations for forestry being one step behind many other industries in terms of automation, says Ola Lindroos. One is that the forest environment is varied and changes rapidly, for example due to heavy rain, or snow or fallen leaves. This is extremely challenging for automation development, as it makes for difficult decisions. Another explanation is that funding for the new technology is poor, especially in comparison to space research and military research for example, which both have similar challenges. In order for the forest industry to have the incentive to invest, it is essential to demonstrate profitability, as compared to current technology.

Although the journey to achieving a level of fully automated machinery in Swedish forestry is still a long one, Ola Lindroos believes that the path to getting there is at least as relevant and interesting. Advances in methods for collecting, managing and using data are important steps on the road to smart machines, and eventually to automation. The path forward will benefit machine operators by improving working methods and facilitating performance. And there are already several interesting advances to study.

– To be able to automate, we need to be able to calculate decisions about where the machine should run, and about which trees to fell. That sort of information is already beginning to be available, and it assists the machine operators, says Ola Lindroos.

When will the robots arrive in forestry?

– Getting there, the development will be incremental, where the simpler tasks will first be partly automated and remotely controlled. But it will be a long time before we see fully independent robots in the forest, carrying out all the work themselves, says Ola Lindroos. He continues;

– And by the time that is introduced, robots will be such a natural part of society that it will not be considered strange that they are also used in forestry.

Just as in previous mechanisations, people will not be replaced completely, but it will enable them to avoid work that is repetitive, boring and dangerous. Development will lead to the creation of new jobs, monitoring, servicing and repairing the robots.

– It might not be the first thing that strikes us, but the ones deciding how automation technology is used to make our work and life fun and meaningful, is in fact people ourselves. So even in the future, it will be up to employers and employees to cooperate in creating appropriate organisations and relevant tasks, Ola Lindroos continues.

And this is something that Ola Lindroos emphasises:

– Robots must facilitate work for human beings, making it more efficient, safer and more fun to work in forestry – otherwise we might as well leave them out!

Photo: Andreas Palmén

OLA LINDROOS

Collaboration with Canada around common challenges in digitalising forestry

Mistra Digital Forest comprehends a number of international collaborations – including with Canada – a country that shares the same ambitions regarding digitalisation of forestry that Sweden does. As part of the collaboration, in the autumn of 2019, Skogforsk, one of the program partners in Mista Digital Forest, participated in a study trip to Canada with a focus on digitalisation and automation in forestry.

– The Canadians show great interest in forestry and automation and what we are doing in Sweden, says Erik Willén, Process Manager in digitalisation at Skogforsk. He is the leader of the work dealing with efficient forestry in Mistra Digital Forest, and one of the participants in the study trip.

The trip began with a visit to Laval University in Quebec where the Swedish representatives met the research consortium for FORAC, which currently consists of 13 active students. FORAC, which stands for Forest to Customer, is a new research program in Canada focusing on data management and decision-making for a more efficient timber supply system. Like Mistra Digital Forest, the program is implemented in close collaboration with industry – in this case in Quebec.

Photo: Image from study trip in Canada

Francis Charette, Associate Research Leader at FPInnovations and Coordinator of Forestry 4.0, together with Erik Willén and Olle Gelin from Skogforsk.

During a visit to the McGill Uni Robotics Lab in Montreal, which is part of a robotics network with close links to the mining industry and other industries, the participants were taken on a tour. Amongst other things, they studied the simulation of crane movements, robotics for felling and autonomous driving with models.

The study trip was concluded together with the Forestry 4.0 steering group – an initiative that was launched in Canada nearly two years ago, and can be compared to the Canadian equivalent of Mistra Digital Forest. Francis Charette, Associate Research Leader at FPInnovations, who are behind the initiative, also participated in Mistra Digital Forest's first program conference in May 2019, to present Forestry 4.0.

During the study visit to Canada, the Canadian Steering Group for Forestry 4.0 outlined a number of successful contributions. Among the achievements they highlighted were successful attempts at platooning (timber trucks that communicate wirelessly, and run closely after one another), mobile laser scanning tested on miniature vehicles prior to mounting on forest machines, and satellite communication in the forest, where great hopes rest on low-flying satellite systems.

In turn, Skogforsk presented Mistra Digital Forest: – I felt that there was a great deal of interest in how our future cooperation could be further developed, and many reflections about it, concludes Erik Willén.

FORAC showing their robot, during discussions about collaboration at Laval University in Quebec.

Photo: Bilder från studiebesök i Kanada

QUEBEC

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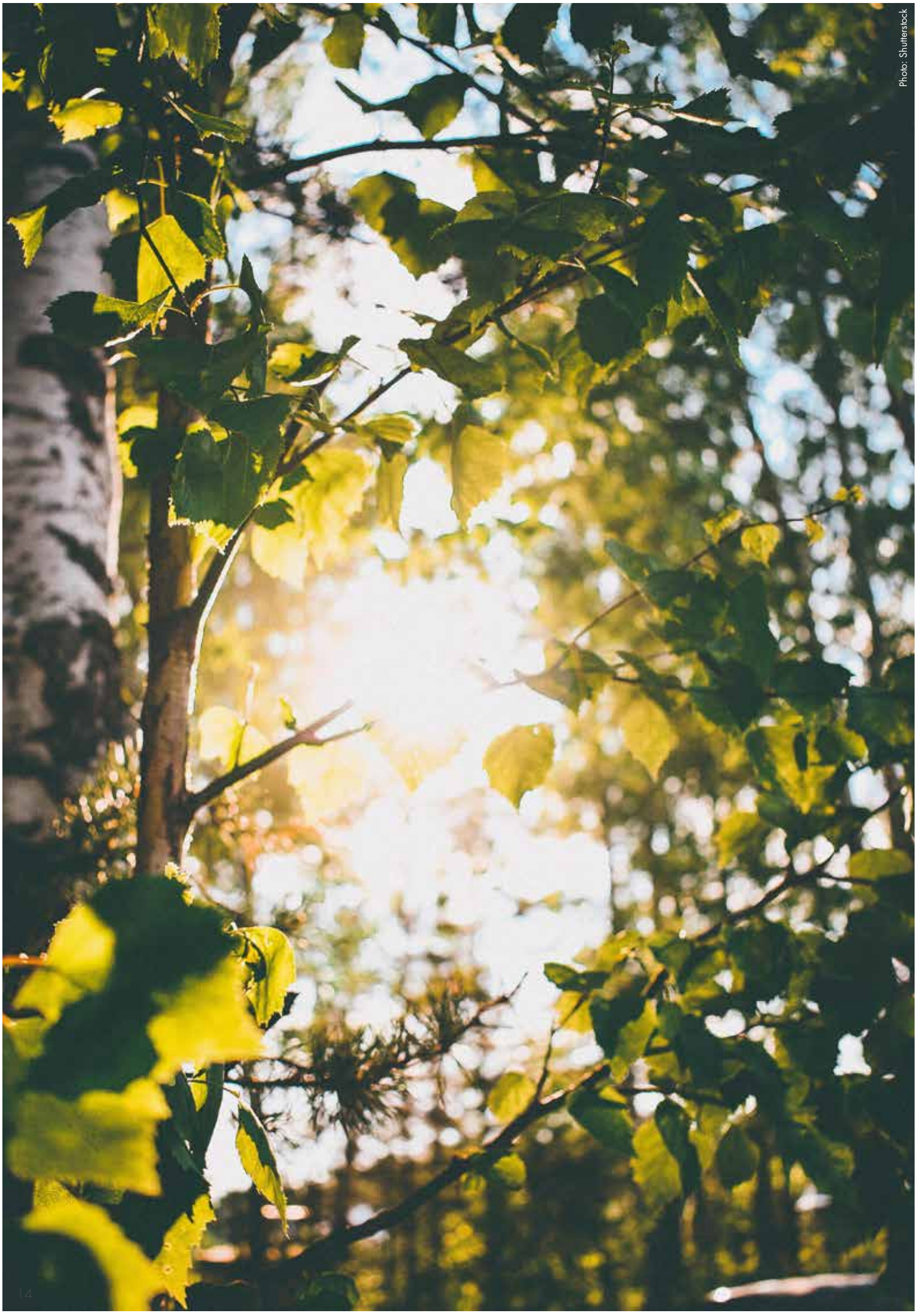

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SCIENTIFIC PUBLICATIONS 2019

SCIENTIFIC PAPERS

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Simulation-based comparison between two crane-bunk systems for loading work when considering energy-optimal motion planning, International Journal of Forest Engineering
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Karlsson, PE. et al. (2019)
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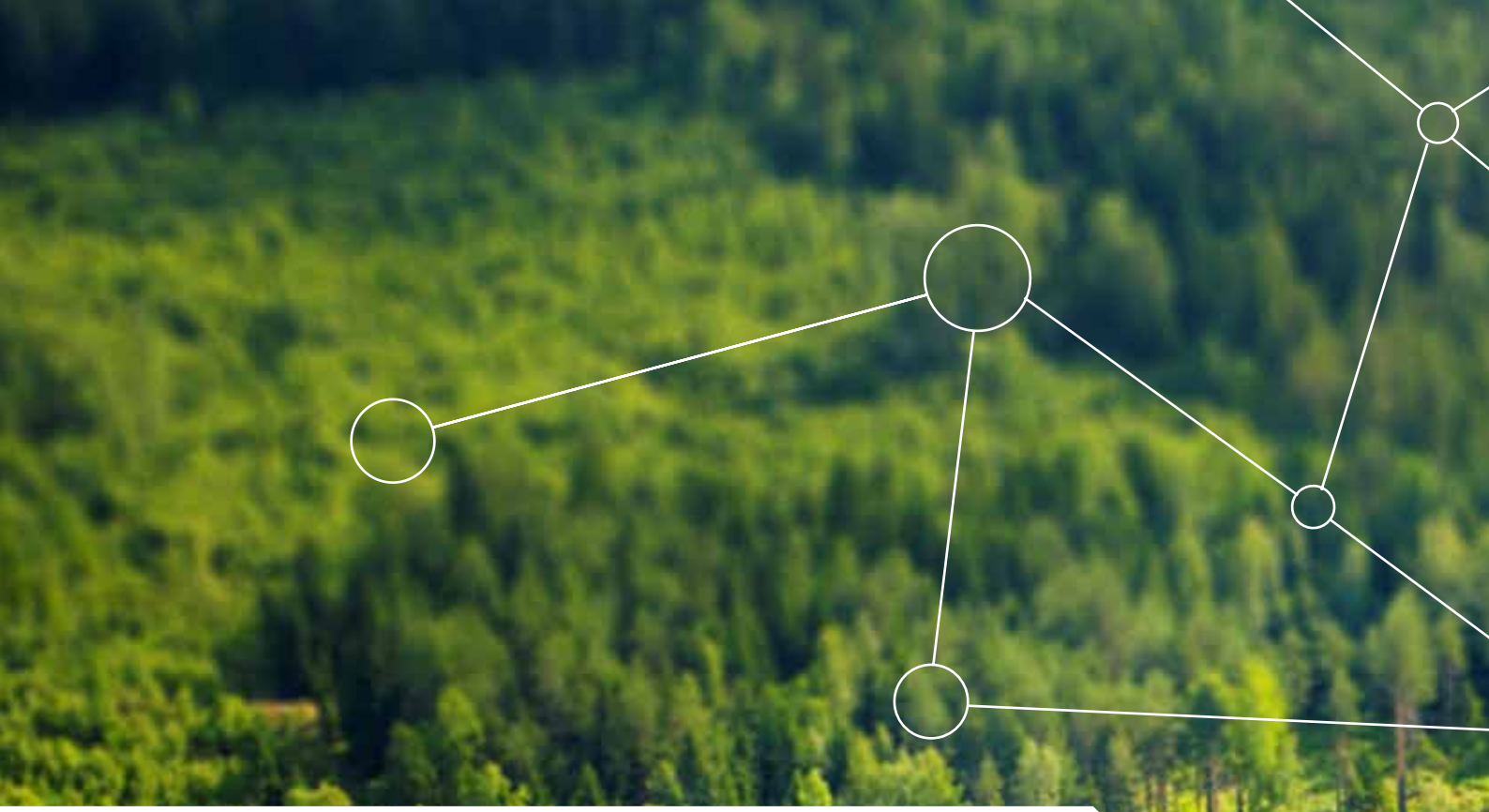
Nilsson, Å. et al. (2019)
A conceptual framework for the BioMapp tool that describes material flows from the forest including tree properties from tree to product (IVL)
(only avaliable in Swedish)

Olofsson, K. (2019)
Automatic detection of stem profiles from terrestrial laser data in areas to be harvested (SLU)
(only avaliable in Swedish)



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