Knowledge and Technologies for our Forests of the Future

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Recommeded citation: TECH4EFFECT. 2020. Knowledge and technologies for our forests of the future.

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Cover Photo: Raffaele Spinelli

TECH4EFFECT

BBI JU

Bio-based Industries Consortium

Horizon 2020 European Union Funding for Research & Innovation

Disclaimer: This publications has been produced with the funding from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 720757. The opinions presented are the sole responsibility of the authors and do not reflect those of the donors.

Contents

Wood, forests and the bioeconomy

The circular forest-based bioeconomy is firmly anchored in the understanding of an economy which combines holistic, responsible and integrated management of natural resources, and products designed for circularity. Ecosystem services play a major role in production, mitigation and resilience of European forests.

To develop a European bioeconomy we need to build on a sustainable resource and use its potential. European forests are important and have the potential to contribute well to the bioeconomy. In promoting the long term sustainability of European forests, management regimes are being revised in an attempt to find the perfect combination of increased volume production, species and spatial diversity, as well as the overall resilience needed in weathering the increasing number of natural disturbances being experienced.

Investments in the European bioeconomy can only be justified by the knowledge that the resource base represents a sustainable and consistent source of raw materials. To be able to supply the new green economy with these materials without compromising the health and well-being of our forests and our citizens, there is a need to incorporate the potential offered by the development of modern digital tools and management solutions. These will form part of an intelligent and low-impact value chain management, which to a far greater degree than in the past, will provide the information needed in truly balancing the environmental, economic and social impacts of the sector.

There are currently advanced machine systems as well as technological and management solutions for most geographical conditions. The collaborative research project TECH4EFFECT (www.tech4effect.eu) improved and tested some of the most promising new systems, such as winch-supported harvester and forwarder in steep terrain, and assessed their economic, environmental and social impacts as compared to the current systems. Mechanization along the value chain is one of our recommendations.

The current wood value chains are still too sectoral and the different actors and stages too disconnected which lead to time, energy, emissions and also volume of materials being lost or underutilized. Improving information flow and increased digitalization on the processes and between the different actors and steps of the process chain has future optimization potential.

Forests play a crucial role in bioeconomy development

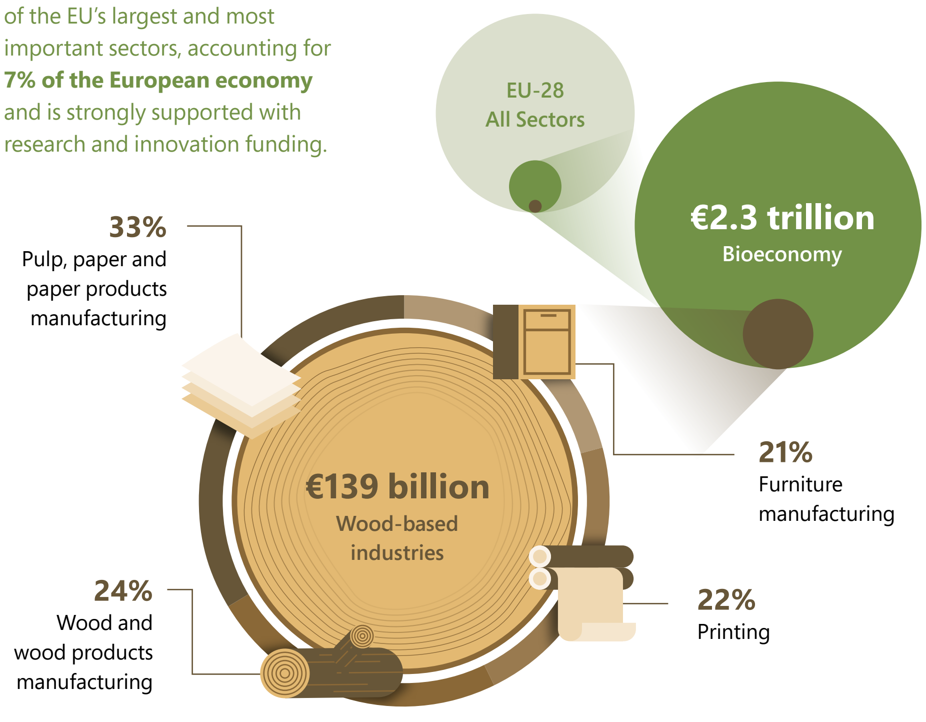
As we move towards a more circular and bio-based economy the demand for wood and wood-based products is likely to increase.

Bioeconomy refers to moving from our current linear fossil fuel-based economy to an economy where renewable biomass is utilized for bio-based materials, products, energy and chemicals and used circularly. Across Europe, the demand for biomass to be used as renewable energy has already increased and this trend is expected to continue.

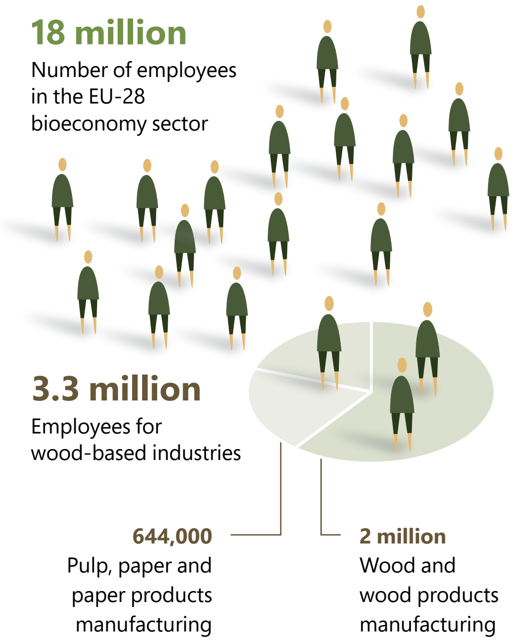
There are considerable potential forest-based resources available for wood supply as forest growth has significantly exceeded harvested volumes in most European countries for decades. Yet mobilizing the existing available wood resources can be a challenge: many forests are located in environmentally sensitive areas or have high intrinsic conservation value, while in other areas harvesting wood is not economically feasible because the costs are high or the conditions for harvesting are difficult, e.g. because of steep slopes or remoteness. Also, as a large part of the European forests are privately owned, all private forest owners may not be willing to sell wood from their forests, or their main objectives for managing their forests may be recreational use or nature conservation. In addition to their production function, European forests have an essential role in safeguarding

THE EUROPEAN BIOECONOMY IN NUMBERS

The European bioeconomy is one of the EU's largest and most important sectors, accounting for **7% of the European economy** and is strongly supported with research and innovation funding.



It is estimated that bio-based industries could create up to **one million green jobs** by 2030, especially in rural and coastal areas



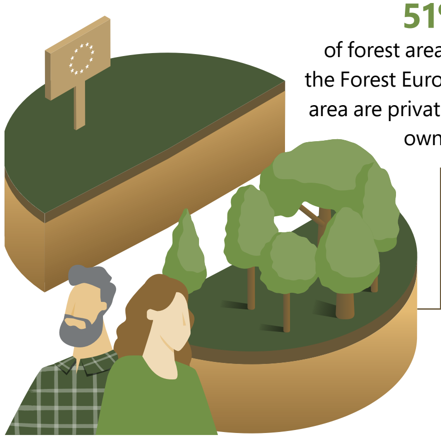
Sources : EC 2018, 2019; Eurostat 2018; ENRD, 2019

Terrain can make forest operations challenging, but for most conditions advanced solutions exist.

Photo: Raffaele Spinelli

biodiversity, maintenance of life-supporting ecosystem services and are of utmost importance to human well-being and health.

In a developing the European bioeconomy, an expected increase in the use of forest resources can have negative environmental impacts, too. Recently, there has been a lot of discussion about the optimization of carbon stocks in forests and the trade-off between the increase in forest biomass utilization and biodiversity conservation. Researchers, foresters, extension services, forest companies and policy makers are therefore constantly looking for new innovative incentives to guarantee a sufficient supply of wood to fulfil the rising demands while at the same time also safeguarding the other ecological and social forest functions. These involve not only technical and management innovations, but also for example new ways of co-operating and communicating between different actors in the forestry sector. In addition, digitalization may play a significant role in the future.



51%
of forest area in the Forest Europe area are privately owned

321–406
million tonnes dry matter/year
Range of total forest availability in EU-28

268
million tonnes/year
Reported roundwood production

The European Union (EU) accounts for approximately 5% of the world's forests, and the forested area of the EU is slowly increasing. Forests are one of the major natural resources in Europe, covering about 42% of the land area. With an active forest industry, most forests in the EU are managed according to principles of sustainability (Forest Europe 2015). Forests and wood products – both from virgin and recycled uses – feature heavily in the circular Bioeconomy Strategy (2018). To be sustainable, this demands resilient management of the European forests, while increasing material supply. The EU Bioeconomy Strategy was launched back in 2012, addressing the production of renewable biological resources and their conversion into bio-products and bioenergy. The 2018 update aims for the deployment of a sustainable European bioeconomy to maximize its contribution towards the 2030 Agenda and its Sustainable Development Goals (SDGs), as well as the Paris Agreement.

How can we improve forest growth?

Tree growth is restricted by one or more of the following factors: light, water or nutrients. These factors determine, through natural selection, how a forest stand can grow in volume. Thinnings remove selected trees and thus help to concentrate forest growth on a reduced number of stems, making forests "grow faster".

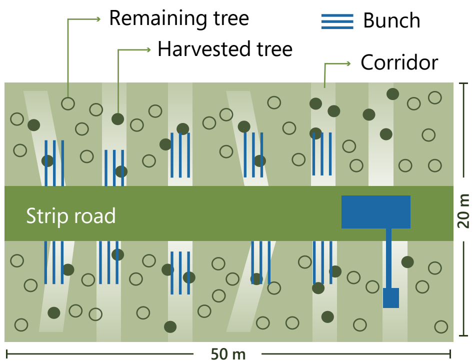
By intensifying forest management, forest growth and timber production per unit of land area can be increased

Timber production per hectare can be increased on upland forest sites by using appropriate site-specific regeneration methods and materials, tending of seedling stands, commercial thinning, and nitrogen (N) fertilization over a rotation. In the long term, the use of improved regeneration materials could greatly increase timber production per unit land area.

Improving thinnings in young stands

Mechanization of forest operations is a key factor in increasing the access to wood resources and capturing additional volume through such operations as thinnings. More efficient forest operations allow silvicultural treatments, which in turn increase the growth rates in forests. Thinning is a prime example of this – its benefits are well known but as thinning operations are often unprofitable due to the low volume removed per treatment, they are not always carried out. The same happens with tending of young stands; success or failure in tending has long-term effects on stand development and, subsequently, on the profitability of forest management. The costs of tending and clearing operations after the regeneration of the stand have been especially increasing. In addition, the availability of labour can be a restricting factor due to high seasonality of silvicultural work. As a consequence, many stands remain untended.

Schematic description of the plot of operator-based corridor thinning method used in the treatment plots.



Source: Yrjö Nuutinen, TECH4EFFECT deliverable D2.2.

The productivity of conventional mechanized first thinning systems is still too low and the costs too high in young dense stands. Eberhard and Hasenauer (2020) have shown that substantial cost savings are possible with adequate training of machine operators. A possible cost-effective alternative for the future could be to develop rationalized methods like mechanized boom-corridor thinning (BCT) methods in young stands. This means that all trees are removed from 2.5-m wide corridors and the areas between the corridors are left unthinned. Witzell et al. (2019) concluded that BCT may potentiate early outtake of forest biomass for e.g. energy or biorefineries while simultaneously maintaining the stand structure's vertical heterogeneity and thereby supporting biodiversity.

Climate change affects forest growth

Climate change affects forest growth and timber production in upland boreal forests due to longer and warmer growing seasons, increase in atmospheric CO_2 concentrations and supply of available nitrogen for growth. Higher summer temperatures and associated drought most probably decrease the growth and volume of Norway spruce under changing climate, but with intensive management forest owners can compensate the losses. On the other hand, minor climate change is in general expected to favour tree species such as Scots pine. In these circumstances, the role of active forestry becomes more significant. As conditions for cultivating more southern species may improve, new opportunities for silvicultural utilization of different species may appear. At the same time, in the Nordic countries climate change shortens the window of opportunity for harvesting on frozen ground, which makes it challenging to harvest the same volume we are currently harvesting.

There is high potential for the use of mechanized harvesting systems in Europe. This should encourage the development and improvement of mechanized systems for silvicultural practices and harvesting. Making forest operations and silvicultural treatments efficient is the key for their actual implementation at forest sites. Minimizing negative environmental impacts like soil disturbance and residual stand damage should also be of high priority when developing and improving mechanized systems. Mechanization is one way of making forest operations more efficient while also increasing the safety at work and lowering the physical stress of the forest workers.

Photo: Raffaele Spinelli

How can we improve forest operations?

In order to meet an expected increase in the demand for wood in the near future, we need to find ways to make harvesting more efficient. In Europe, many forest stands are on terrains which are difficult to access without specialized machinery.

Factors that affect the productivity of forest operations include fuel efficiency, energy use, greenhouse gas emissions, and harvested volume per hour. We can improve this efficiency by increasing the productivity per hour and making sure it exceeds any subsequent increases in operating or ownership costs. Improvements in fuel efficiency and reductions in fuel consumption can also contribute, as shown in recent studies.

Fuel consumption can be reduced by adapting the machinery

One of the questions researchers have been asking is how to reduce fuel consumption and CO_2 emissions. Just as some cars have an eco and a sport mode, Prinz et al. (2018) examined if changing the various technical settings of the harvesting machine's operating software could help.

Excavator-based harvesters offer many advantages compared to purpose-built harvesters in easy terrain. This led Spinelli and de Arruda Moura (2019) to study if the fuel efficiency of excavator-based harvesters can be increased by a better interface between the excavator and the harvester head. The study investigated the performance of a new adaptation kit, specifically designed to improve the communication between these two components with the new kit offering real-time adjustment between the power demand of the harvester head and the power output of the excavator. As a result, after installing the adaptation kit, productivity increased 6%, while fuel consumption decreased 3.5%.

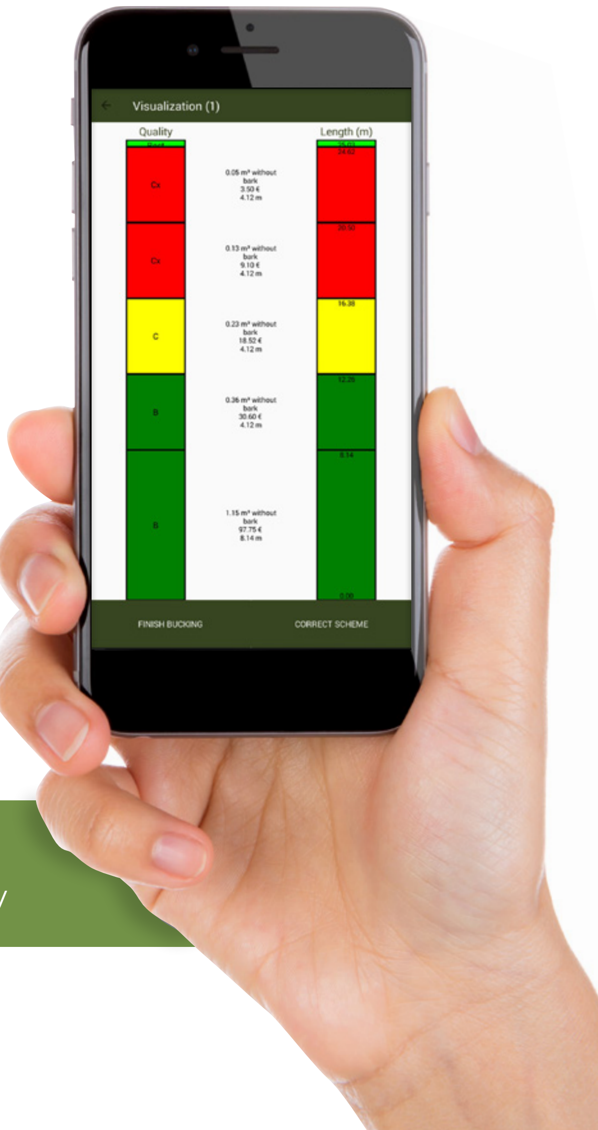
Safer harvesting in steep terrain is very challenging for harvesting. New winch supported systems have been a game changer allowing harvesting and forwarding in slopes up to 70%.

Developing machinery, such as combining tethered harvesters with grapple carriages increases productivity and improves worker safety by removing the dangerous positions of timber faller, choker setting and landing chaser. These tethered harvester-forwarder systems have replaced the more expensive and less productive cable logging systems on some steep sites, but there is concern about the dynamic cable tensions exceeding the safe working load for the tethered cable. However, there are fewer workers exposed to the high hazards than in manual cable logging systems.

Supporting the chainsaw operators with a new technical solution – the Bucking App

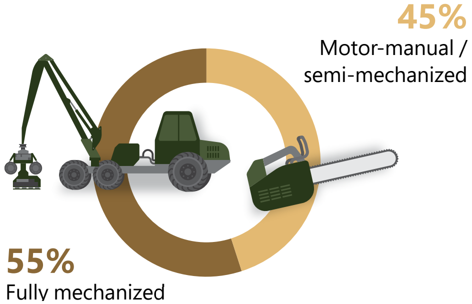
When timber is harvested, trees are felled and cut, or bucked, into pieces of different length, which are called assortments. Pricing of these assortments depends on their length, diameter class and quality and is given in euro per m^3, which is then multiplied with the respective volume. On a harvester, all this is taken care of automatically by the on-board computer. During motor-manual felling and processing operations, the chainsaw operator is the key person to determine which assortments to cut from a given tree. This optimized cross-cutting of the tree into the most valuable combinations of logs has shown the potential to increase value recovery by over 40%. In valuable species (oak, cherry, ash) this can be even larger.

There are technical tools that support the operators in their decision making. One of them is the Bucking App, which is an application for Android OS mobile devices which provides support on the best log size to make, and can be used in education and training as well as on site by professional chainsaw operators.



The Bucking App has been developed in the Tech4Effect project and more information can be found at www.tech4effect.eu/results/bucking-app/

CURRENT WOOD VALUE CHAINS (EU-28)



Modern equipment requires new skills from operators

Current wood value chains are 45% motor-manual / semi-mechanized with chain saw operators carrying out the fellings, and 55% fully mechanized, which means harvesters and forwarders are used. Forestry is an important source of income particularly in rural areas, with many regions in Europe leaning towards motor-manual / semi-mechanized harvesting. Chain saw felling is comparatively slow, physically heavy and dangerous work, and it requires skilled and fit workers, working in teams. The risk for accidents is higher after hazardous events like storm throws, snow breaks, bark beetle attacks or fires when trees are under tension and may snap or break unexpectedly. The current workforce is limited and aging, and will not be enough to provide the anticipated amount of wood needed for the development towards the more sustainable and circular forest-based bioeconomy that the EU is targeting.

In harvester fellings, the worker is safe in a machine cabin, and has a strong crane arm and higher vantage point for felling. The processing speed is higher and thus (depending largely on labour costs) the whole operation tends to be cheaper. Future forest value chains will need to employ the most appropriate level of technology available, which is expected to include more digital solutions and mechanized fellings. This applies particularly in Southern and Eastern EU, where the current rates of mechanized felling are 24% and 9%, but also in Central EU, where mechanization is 41%. Forest operations in Northern Europe tend to be almost entirely fully mechanized.

Timber harvesting is a very complex activity that requires the completion of simultaneous gestures often overlapping, increasing the operators' mental workload. We need to ensure that we train and recruit the right people to operate and maintain the modern forestry equipment efficiently. Modern harvester multi-functionality sets requirements for adequate computer skills and persistent situation awareness among operators. In addition to the regular harvesting activities, the more frequently occurring natural disasters such as storms, bark beetle infestations and fires require a work force with specialized skills. This will have consequences in work force training, machine availability and entrepreneurial activity. It should be noted that while the emissions from the motor-manual system are lower than from the mechanized one, it would be impossible to reach the needed felling volumes by continuing the motor-manual option.

Modern forest machines offer safe and ergonomic work environments in the forest. The worker is safe and comfortable in a machine cabin, all operational data is digitally recorded and supported.

Photo: Ponsse

How can we reduce soil impact?

Healthy soils maintain productive and healthy forests, purify ground water and regulate stream flow. They are crucial to productive forests and maintaining such ecoservice functions as protection and provisioning. Soils are made up of fine networks of structures, harbouring diverse strata of biodiversity, and holding the chemicals and compounds essential to plant life.

Information on soil moisture is crucial for forest operation planning to avoid soil damages.

Photo: TECH4EFFECT

Wet soils are fragile soils

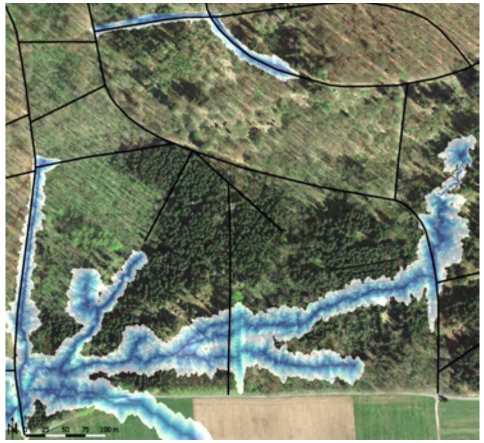
As traffic on wet soils should be avoided or reduced as much as possible, there is an increasing need to predict the times when and areas where machines can access the forest without sinking in or destroying soil structures. This is called soil trafficability. Forest operations are therefore affected by climatic conditions that reduce soil trafficability, now more frequently than before.

During the periods of high precipitation and less intensive frost that freezes the ground, machine traffic causes more soil disturbance. Their extent and severity can often be managed through a greater awareness of their causes and effects. For example, wheel rutting and compaction can damage the future production potential of the site and increase the spread of diseases such as root rot, thus reducing future timber revenues. In addition, wheel sinkage and slippage directly increase the cost of timber extraction through higher fuel consumption and lower productivity.

Wet soil conditions reduce soil bearing capacity irrespective of the soil type. The Depth-To-Water-algorithm (DTW) is a method that helps to identify critical areas. Drivers can then avoid these areas and find more suitable tracks. In a recent pan-European study, we validated the accuracy of DTW-maps by establishing study sites in Finland, Germany, Norway and Poland. The maps created in this study are available on the TECH4EFFECT Mapping App, which is a handy tool for field operatives to access DTW-maps and supplementary data.

Furthermore, if machine operators are aware of sensitive areas in advance, a handful of expedient preventive measures can be applied during the harvesting operations. One of these is the application of winch traction-assist technology to heavy forest machinery during harvesting operations. The results of a conducted field trial give clear evidence, that winch-assist technology can reduce wheel slippage to a minimum even in flat terrain.

In addition to management alternatives, technical modifications were shown to have a significant effect on reducing wheel rutting and give the forest manager a real option for minimizing impact.



Soil moisture mapping is a technique that is becoming widely adopted in providing information on an area's sensitivity to soil disturbance and allows forest managers to adapt their plans accordingly.

Potential effects of enhanced production and improved forest operations in the EU

The overall level of EU-28 roundwood production reached an estimated 387 million m^3 in 2018. In model calculations these actual fellings were contrasted by the sustainable potential of wood supply.

The total potential availability of woody biomass for all uses from forest resources in the 28 EU member states is estimated at 335 million tonnes dry matter yr^{-1} overbark in 2020, equalling 722 million m3 yr^{-1} overbark.

By enhancing production and improving supply, by 2050, this potential could increase to 409 million tonnes of dry matter yr^{-1} overbark. Without stumps this potential is 365 million tonnes of dry matter yr^{-1} overbark, equalling 797 million m^3 yr^{-1} overbark. In all calculations, the felling levels never exceed the annual increment and excludes environmentally fragile areas.

Typical value chains for primary domestic biomass production were modelled for four EU regions: Northern, Central, Southern and Eastern EU.

Forest operations are important for maintaining and increasing employment in rural areas.

Photo: Raffaele Spinelli

TABLE 1 The potential removal volumes for the Baseline 2020 per country group and total, as well as for the combined scenario 2050.

Mill. m^3 yr^{-1} overbark	NEU	CEU	EEU	SEU	EU-28
ACTUAL 2018 Actual production of roundwood in EU-28 (mill. m^3 yr^{-1} overbark)[1]	164.4	95.1	89.9	37.9	**387.3**
BASE 2020 Potential availability of woody biomass (mill. m^3 yr^{-1} overbark) for the base scenario in 2020 (excluding stumps)[2]	252.2	232.4	141.6	96.2	**722.4**
COMBINED 2050 Potential availability of woody biomass for the combined scenario in 2020 (excluding stumps)[3]	299.6	252.1	143.7	101.9	**797.3**

Source: [1] According to FAOSTAT 2018 [2] Modelled results [3] Enhanced productivity and improved mechanization based on Verkerk et al. 2019 and modelled results

Indicators for EU-level baseline and scenario

Harvesting and supplying these hypothetically available potential volumes, would have consequences on the current forest-based sector. Namely an increase in energy use and greenhouse gas emission, in employment potential and need for workers (and machines), and in production costs (simultaneously potential for entrepreneurial income).

Indicators chosen for this study were employment (FTE), production costs (€), energy use (MJ) and consequent greenhouse gas emissions (CO_2e). The indicator values for the actuals (2018), and the modelled baseline 2020 as well as Combined scenario 2050 for the whole EU-28 level are presented in Table 2. It is clear that increased mechanization increases energy use and subsequent greenhouse gas emissions, however, the harvested forest biomass also increases significantly. With enhanced production and improved supply, also employment and production costs face increases, thus creating jobs and contributing to GDP.

Energy use is derived from the fuel usage of forestry machinery and presented in megajoules. Energy use in Combined 2050 scenario is increasing heavily compared to the baseline. This increase is triggered by the increase in harvesting more volume and transitioning from manual harvesting to energy-intensive mechanized harvesting.

Greenhouse gas emissions are presented as CO_2 equivalents representing global warming potential. In this study, emissions were derived from fuel used by forestry machines in operations. As the energy use in Combined 2050 scenario is increasing due to larger harvested volumes and transition from motor-manual to mechanized harvesting, greenhouse gas emissions increase from 3805 million kg CO_2-equivalent to 5040 million kg CO_2-equivalent. The only possibility to make drastic large-scale cuts of the emissions from machinery fuel use would be using biofuels. It is estimated in the revised renewable energy directive 2018/2001/EU, REDII, that replacing fossil fuel with rapeseed biofuel would reduce emissions between 47 and 52 %. While these values show great potential of cutting greenhouse gas emission into half, an extensive study on the large-scale availability of biofuels for harvesting operations and consequences on the competition with other sectors was outside the scope of this project. That being said, wood – as natural and regrowing material – is in its chemical composition built from 50% carbon[1] obtained through photosynthesis[2], in which trees absorb CO_2 and release O_2 while storing C as one of the structural components. That means that while the emissions for harvesting roundwood equal between 2.7 to 11.6 kg of CO_2 equivalent per cubic metre (dependent on where in Europe and how it has been harvested), the same cubic metre stores ca 400 kg of carbon (dependent on tree species).

Production cost increase slightly in the Combined 2050 scenario compared to baseline. While mechanized harvesting tends to be cheaper than manual harvesting due to the fact that with efficient machines, less work force per cubic metre of harvested forest biomass is needed, this change too is triggered by increased mobilization volumes. Entrepreneurial opportunities are enhanced with increased possibilities to harvest. The GDP of countries with more significant changes in harvesting volumes is enhanced.

Wood is a natural and regrowing material, that captures carbon from the atmosphere and stores it in the forest and in the wood products.

Photo: Raffaele Spinelli

TABLE 2 Indicator values for the whole EU in baseline and scenario

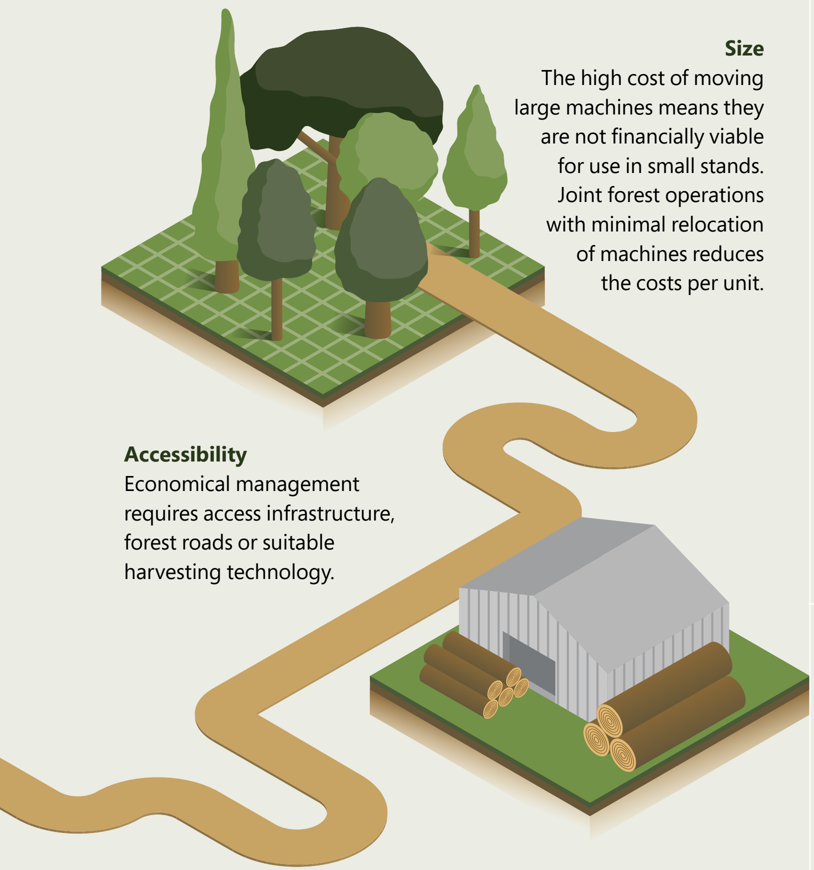
Indicator	Actual 2018	Baseline 2020 (modelled)	Combined scenario 2050 (modelled)
ENERGY USE, BILLION MJ	29.19	52.43	67.66
GHG EMISSIONS, MILLION TONNES CO_2E	2.11	3.89	5.04
EMPLOYMENT, THOUSAND FTE	125	254	278
PRODUCTION COSTS, BILLION €	6.28	12.65	14.04

[1] Chemical composition of timber (with species-specific variations): approximately 50% carbon, 42% oxygen, 6% hydrogen, 1% nitrogen, and 1% other elements (mainly calcium, potassium, sodium, magnesium, iron, and manganese) by weight.
[2] Formula for photosynthesis $6CO_2 + 6H_2O \text{------>} C_6H_{12}O_6 + 6O_2$

INFOGRAPHIC

WHAT FACTORS AFFECT THE MOBILIZATION VOLUMES OF FOREST BIOMASS?

Forest stand characteristics



Size
The high cost of moving large machines means they are not financially viable for use in small stands. Joint forest operations with minimal relocation of machines reduces the costs per unit.

Accessibility
Economical management requires access infrastructure, forest roads or suitable harvesting technology.

Location
Transport cost increases with distance, for a low-priced assortments such as energy wood, economical transport distance is rather limited.

Forest owner characteristics

Age and location
Older owners typically live near their forest, while younger generations often live in urban areas far away from forests they may have inherited.

Education
Owners with traditional knowledge or formal training in forestry are likely to be more aware of the various aspects of forest management.

Motivation
The question of whether owners wish to produce timber or want to use their forest differently, e.g. for recreation.

Tradition and finances
Traditional forest owners and farmers are generally more often willing to actively manage their forest, while non-traditional (e.g. urban) forest owners may need some motivation and understand the need for active management. Fluctuating timber prices also influence willingness to cut.

Forest organization membership
Improves cooperation for harvesting, machine ownership, wood price and contract negotiation.

External factors

Cost
(Precommercial) thinnings are an investment that may not bring high or immediate financial return.

Policies and legislation
Guidance for forest owners is available, but not necessarily easy to find and interpret for non-professionals.

Available technology
Machinery is expensive and requires professional training while some sites require specialized equipment.

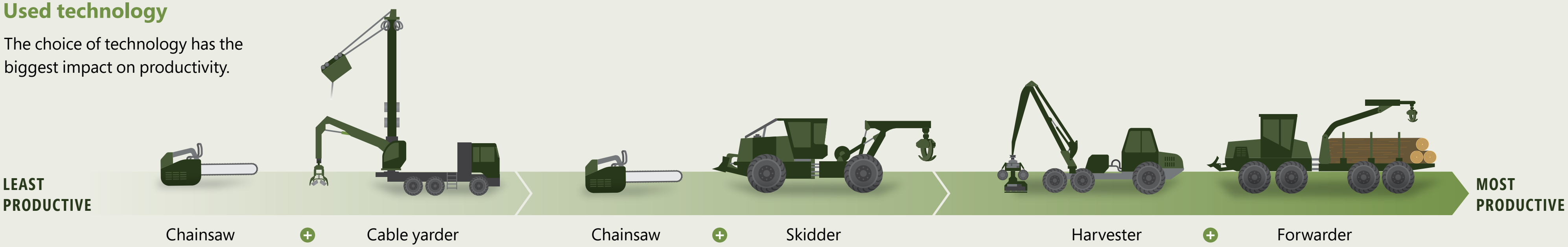
Unclear ownership
Historical developments and relocations mean it may not be clear who to be contacted during calamities such as fire and storm breaks.

INFOGRAPHIC

WHAT FACTORS AFFECT PRODUCTIVITY?

Used technology

The choice of technology has the biggest impact on productivity.

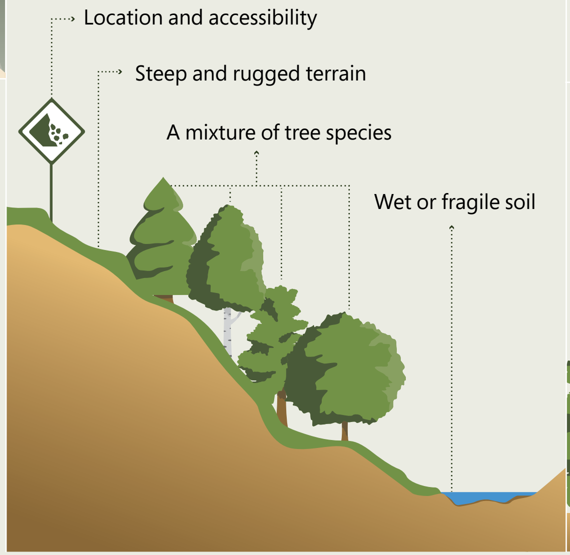


Operator

The person handling the machine has a pronounced influence on the productivity, the so-called Driver effect[3].

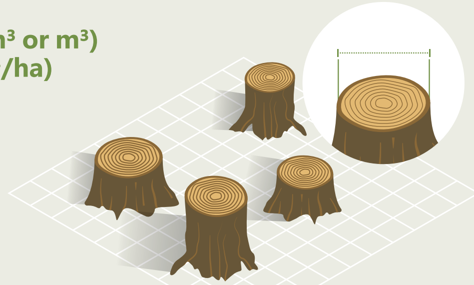
Stand characteristics

The forest can determine the productivity of the operation. Characteristics that make the operation more difficult, slower and less productive include:



Average stem size (in dm³ or m³) and removal volume (m³/ha)

The bigger the harvested trees are and the more trees are removed during one felling, the more volume can be handled per machine hour.



Unit size

Felling operations on a bigger forest stand (ha) or on connected forest sites reduces the amount of time (and costs) for relocating the harvesting machinery and thus also increases productivity.

Number of assortments

Each assortment requires separate sorting: first presorting while cutting by the harvester in the forest stand to speed up the hauling process for the forwarder. And then at the forest roadside by the forwarder as different hauls and heaps.

INFOGRAPHIC

WHAT FACTORS AFFECT THE CHOICE OF MACHINE SYSTEM?

Mechanized harvesting is used and suited for all types of forest management: from close-to-nature to intensive forest management. In addition, mechanized harvesting systems are particularly advantageous for their efficiency in harvesting and high level of work safety. Mechanization has proven to considerably increase work safety and to reduce job injuries and fatalities remarkably.

The protection provided to operators is a crucial advantage when dealing with climate change related disturbances, such as snow break, wind throw and bark beetle attacks. These disturbances are expected to become more frequent. Speed is also essential when dealing with bark beetle outbreaks. The faster the infested trees are felled, processed and transported, the easier it is to contain the outbreak.

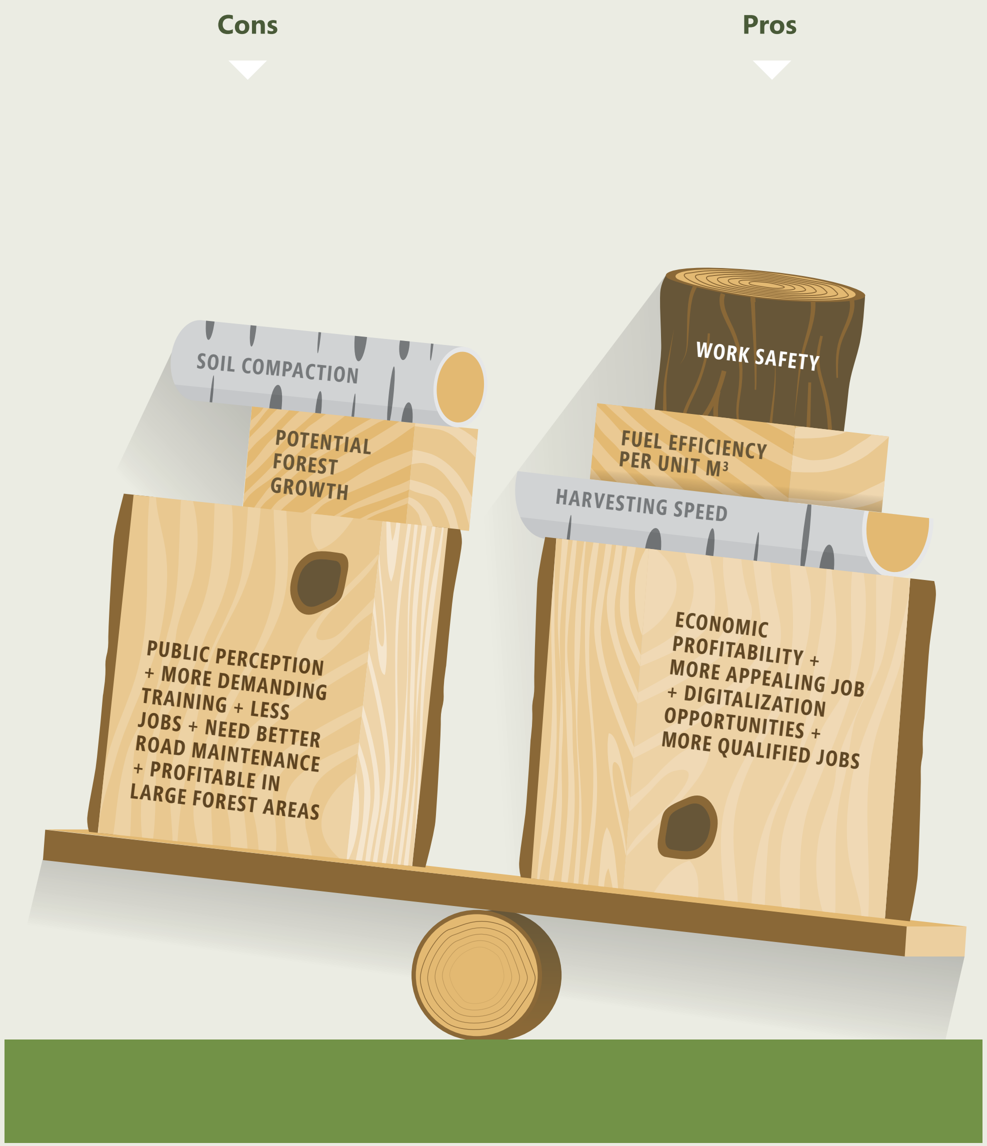
Finally, mechanized harvesting systems are essential in providing the raw materials demanded by society. Since motor-manual forest work is hard, dangerous, often seasonally concentrated, and happens in remote places, traditional forestry suffers from an ageing workforce and is not able to attract as many new entrants as people leaving the industry. Operators in mechanized work environments, however, may be more attractive to the younger generation.

There are three main impacts of mechanized harvesting systems on the forest: damage to the forest soil, to the remaining stand and emissions. TECH4EFFECT included a range of studies which aimed at enhancing mechanized harvesting systems' efficiency, while reducing their impact on soils and emissions.

The project also investigated the use of existing technology on new terrain: in winch assisted harvesting systems, a harvester's and forwarder's traction on difficult terrain is enhanced by a traction winch. The winch's pull considerably reduces slip and thus the potential for soil displacement and erosion. Focusing on productivity and safety aspects, studies showed that productivity on steep slopes is slightly lower than on flatter terrain and that peaks in cable tension usually occur during driving activities. Further studies are aimed at reducing fully mechanized harvesting operations' emissions.

Summarily, TECH4EFFECT has tackled many challenges related to mechanized harvesting while also improving overall operation quality via sharing of information. It is evident that mechanized harvesting operations will be become more important and that highly qualified personnel will need to operate these machines.

Therefore, employing mechanized harvesting systems is neither "good" nor "evil". All forest management has an impact on stand and soils and its extent is primarily a question of proper employment. As TECH4EFFECT shows, forestry is well aware of the challenges and constantly strives to improve mechanized harvesting systems' impact, while securing a high level of productivity to satisfy society's demand for raw material from forests.



The potential role of digitalization

Digital technology has a huge development potential in forest management and production.

Digitalization can be used in a wide range of applications:

- to obtain as much information as possible to support monitoring and decision-making across the whole value-chain, from forest inventory, timber stock management, forestry operations
- improved and uninterrupted information flow between the different actors of the value chain for optimized logistics, management, planning, trading
- to obtain timely and consistent spatial and temporal trafficability of forest sites,
- traceability, digital certification, and
- to an e-marketplace for timber trade.

Digitalization can contribute to reducing costs (e.g. time invested in the forest measurements, operations, flow of information, efficiency of logistics) and increase the sustainability of forest operations (e.g. reducing tree damage and avoiding soil disturbance), improving at the same time data accuracy and thus enabling a smarter and more responsible forestry. These savings, that can reach even 10%, can bring down the cost of wooden construction materials in the future.

Lower costs would also be achieved when aggregating harvesting sites within a short distance, reducing the number or distance of machines' relocations. This becomes of special relevance when using higher level of mechanization in the operations.

Techno-diversity – the key to future success

The term techno-diversity means searching for a variety of technological solutions, which are ecologically and socially adapted to local conditions and needs, since they consider economical capacities of the forest stakeholders. These solutions include autonomous, unmanned robots or tractors with or without human direction which might play a bigger role in the near future. Remote operated machines offer improved ergonomic and safety to the workers especially in steep terrains. New forest machines can reduce the stress on the operator and decrease the learning time they need to reach full productivity. Working with modern high-tech forest machinery requires special education and experience, and ability to work with several IT-software, thus it will require needs for educational organizations and well-trained operators.

Digital efficiency portal SILVISMART

In this context, precision forestry, with its associated digital benefits, has yet to be fully implemented across Europe. The digital efficiency portal SILVISMART, developed by TECH4EFFECT, is an effective knowledge-based digital tool which has the potential to bring about the next breakthrough in business intelligence and decision support to increase efficiency and environmental performance within the forestry sector.

Photo: NIBIO

SILVISMART provides an essential tool for information sharing between the different, consenting actors in the value chain such as contractors, operators, forest owners and managers. Benefits such as improved digital data flow between the actors can be achieved, reducing the need for manual paperwork related to production reporting and sustainability documentation. Information on tree species, positions, assortments and sites can improve future forest management. Environmental data can be used to document and demonstrate sustainable management, which is required for certification schemes. Personal benchmarking for operators or contractors to allow for continuous improvement and learning would be an additional major step towards efficiency.

A key component in facilitating data sharing and automatic data flow is that independent, reliable systems are in place where the data is safe; where the data collector has full control over what data is being shared; and with whom. Willingness to share data and information is a key aspect of a more efficient and digital future. Increased mechanization, with the advantage of onboard computers, would help enable data collection. In the case of manual harvesting, automatic data collection from these methods are much less developed than for CTL operations, making it a harder case for rapid digitalization.

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