D6.7
Business uptake and exploitation plan- initial phase

Project Acronym: SINTETIC

Project name: Single item identification for forest production, protection, and management Europe

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List of abbreviations

Acronym / Abbreviation	Meaning / Full text
APP	Mobile Phone Application
CLT	Cross Laminated Timber
CTL	Cut-To-Length
DBH	Diameter at Breast Height
DDS	Data Distribution Service
EUDR	EU Regulation on Deforestation-free Products
EUTR	European Union Timber Regulation
FSC	Forest Stewardship Council
GIS	Geographical Information System
GNSS	Global Navigation Satellite System
GVA	Gross Value Added
KER	Key Exploitable Result
ID	Identification/Identity Code
IT	Information Technology
LiDAR	Light Detection and Ranging
NDVI	Normalized Difference of Vegetation Index
PEFC	Programme for the Endorsement of Forest Certification
QR	Quick Read Code
RFID	Radio Frequency identification
SME	Small Medium Enterprise
StanForD	Standard for Forest machine Data and Communication (is a standard for communication between computers in forest machines)
SWOT analysis	Analysis of the strengths, weaknesses, opportunities, and threats
UHF	Ultra-High Frequency (300 MHz to 3 GHz)

Introduction to the business uptake and exploitation plan

The Business Uptake and Exploitation plan is a living document evolving with the project's development. Its role is to define the strategy to facilitate a market uptake of the solutions and technologies developed in SINTETIC.

The main target of this plan are the companies involved, who are the main beneficiaries and actors of a future market penetration and commercial valorisation of the concept and its components. Yet, the whole consortium is involved in the achievement of the targets set by D 6.7 and its following releases (D6.14 and D6.15). Additionally, research centers and universities are increasingly interested in IP policies as a means of trying to accelerate the transformation of research-based inventions into industrial processes and products. By strengthening collaborative ties between academia and industry, these policies facilitate the seamless transition from research to practical application.

Based on the **analysis of the Key Exploitable Results and their specific market niches**, the present document aims at defining the potential scope of the business uptake. This will be done through a **Preliminary market analysis**, focusing mainly on the European forestry sector. Following, the report will describe the **main potential constrains to the implementation** of the technologies and services proposed, to be addressed throughout the development of the project with appropriate actions.

The following deliverables, integrating and expanding the scope of the present Business uptake and exploitation plan will focus on the following:

- D 6.14, detailed evolving path for the project's products developed in the first phase of the project. It will include a more detailed market analysis, contrasted and verified by a validation by the relevant stakeholders of the forest value chain. An initial exploitation plan will be included.
- D 6.15, reporting the final assessment of SINTETIC exploitable results and assets, value proposition and business models for each KER identified.

Mapping the Key Exploitable Results

The technology development planned in SINTETIC is meant to provide several innovative tools, instruments and services. These are designed to be deployed independently or to be combined in more complex and ambitious set of services. The list of Key Exploitable Results (KER) resumes the main technological outputs of the project (Table1).

Table 1 Key Exploitable Results (KER) planned in Grant Agreement

KER	Description
Entire value chain traceability system for forest products **(mechanical and manual)**	The traceability system, based on physical marking of roundwood (single logs) and deployed with a simplified data platform allows stock management, product invoicing and enables a highly precise certification of forest products, including origin georeferencing.
Identification and traceability system for sawnwood	This system when deployed within the primary processing industry allows: - Accurate traceability of resources along all log transformation steps - Link the final product (such as long-lasting structural components) to the unique tree standing in the forest
On-board LiDAR scanning for value recovery optimization and forest inventory	The elaboration of LiDAR data can provide two independent services: - Real-time optimization of value recovery during tree harvesting - Elaborate a detailed post-harvest forest inventory
Smartphone APP for forest inventory and timber measure	It can be deployed in two different stages of the forest value chain: - Inventory of forests for value assessment - Measure of produced timber during manual harvesting
Illegal logging satellite detection	Early warning solution for the detection of forest cover changes based on free Copernicus data. Applicable to control illegal logging but also to monitor natural hazards (e.g. wildfire or storms)

KER 1 - Entire value chain traceability system for forest products

Brief description

The traceability system deployed for the SINTETIC project is based on two alternative technologies, RFID and optical. Because of their distinctive characteristics, each option offers unique opportunities and optimal application, making each one best suited for a specific logging operation. The project aims to develop both of them, enhancing the individual functionalities as well as the potential for a synergic combination in a unique application. Specifically, the technologies to be deployed include:

1. Radio Frequency identification (RFID) systems provided by the partner Simtrona (SIMTRO). This technology is designed for marking standing trees, round timber and all types of wooden products and semi-finished products enabling permanent marking with dedicated equipment. This equipment typically

consists of an applicator, which can be manual or automatic, passive RFID tags operating in ultra-high frequency (UHF), and readers capable to identifying the unique ID of each tag. Also, the readers can be manually operated, installed on machinery, or fixed (e.g., at the bridge of a mill's gate). RFID-UHF technology is particularly well-suited for manual systems, but in the frame of the project it will also be integrated into fully mechanized operations with harvesters. One of the key advantages of this technology is the possibility to read the tags at a distance (approximately 1-8 m, depending on several factors and external conditions) even without direct visual contact with the tag (e.g. in case it is hidden by dirt or mud). Additionally, tags can also be collectively identified through bulk reading, for example, when scanning a truckload. The main drawback for this technology is the unitary cost of tags, ranging from 0.55 € to over 0.75 € depending on the model and the quantity purchased. Regarding the possible disturbance caused by non-woody material in the residual flow of the sawmill, this issue has been addressed by using a special composite structure. The composite structure, which is primarily made of vegetal fibres and resins, aims to mitigate such disturbances effectively.

Figure 1: Operator reading RFID tags on standing trees with manual reader (source CNR-IBE)

2. Mark punching is an innovative technology developed by Otmetka (OTME). It is designed to stamp a mark directly on the crosscut section of the logs. It is designed to be integrated into timber processor heads and to efficiently stamp roundwood during processing. The system is not suitable to mark the timber through the bark and has limited capacity to punch the ID perpendicularly to the wood fibres, making it unsuitable for marking standing trees. After each application, the mark's shape changes automatically, providing a unique ID to each log. This ID can be retrieved via optical systems, similar to a QR reading, and decrypted using specialized software to access all the log/tree previous information for the traceability. The primary advantage lies in the swift application and low cost, as the mark it is directly impressed onto the timber,

making this method suitable also for roundwood with low unitary value. However as with any optical system, the main drawback is the necessity of a clear line of sight to identify the mark. Additionally, dirt, mud or cracks as well as non-optimal illumination may reduce ID detection reliability. In this project, we aim to address this challenge by integrating this technology with MiCROTEC's CT-log scanner in the logyard (https://www.microtec.eu/en/products/ct-log). By doing so, we anticipate that even in adverse conditions such as when the mark is covered with snow or mud, the ability to read the marking will be significantly enhanced, as density variations should be noticeable.

Figure 2: Punched mark and corresponding ID (left, source Otmetka.com) and punching tool for processor heads (right, source New Zealand Journal of Forestry 2023)

The combination of these two technologies ensures the capacity to mark and trace every item throughout the forest value chain, from the standing tree to the roundwood delivered to the sawmill. Depending on the complexity level of the local forest value chain and the market requirements, either a single technology or a combination of both will be used. Once marked, the IDs of the marks (RFID or punched code) can be potentially identified at any step of the production process and transmitted to the central geodatabase along with several metadata such as geolocalization, tree and timestamp information.

In addition to the certification service it provides, this system possesses the potential to significantly enhance its value by linking to the unique ID a range of digital data generated at each step of the value chain. For instance, the specific ID of trees and logs, together with relevant quality and process parameters (e.g., timber stiffness, log branchiness, etc.) can be seamlessly integrated into the StanForD data (https://www.skogforsk.se/english/projects/stanford/). This is the digital data format (a *de facto* standard), presently generated by most of timber harvesters worldwide, and already accepted and deployed by most timber industries. In the frame of SINTETIC, these data parameters are then securely stored within the central geodatabase, readily accessible at any moment. The scope of application for this integrated approach is extensive, offering a multitude of opportunities to generate added value at various stages of the value chain. Additionally, the system's ability to mark and identify standing trees allows for an integration with forest inventory processes and cutting permits, particularly when utilizing digital instruments. This integration not only streamlines data collection but also unveils opportunities for further optimization and informed decision-making within forestry management practices.

Potential market

Any forest value chain can potentially benefit from this service. Non-industrialized areas would mainly benefit from a very efficient certification system, guaranteeing the provenance of the timber from sustainably manged forests. With a growing degree of development of the market and industrial framework, the potential applications and benefits abruptly increase. This is consistent with the “Industry 4.0” concept, providing added value and competitive advantages through the digitalization of the production processes.

KER 2 - Identification and traceability system for sawnwood

Brief description

This system relies on a set of arrayed sensors strategically installed within the industrial facility, incorporating cutting-edge technologies such as X-ray, optical and laser systems. When operating independently, these sensors provide a full control over the internal production process, primarily aimed at increasing the efficiency and maximizing yield. Additionally, when implemented for batch-level control of processed roundwood, it can also provide the final product certification of provenance.

However, the main potential of this KER is expressed in combination with the previous one. In this case, each log’s unique ID is associated at the entrance of the X-ray tomograph, effectively linking it to the digital ID of each resultant industrial timber product (from the sawmill). This system when deployed within the primary processing industry enables:

- Precise traceability: Offering accurate traceability throughout the timber transformation process, from the standing tree to the board;

- Process optimization: Based on the comprehensive data feedback from the entire value chain to optimize processes. This includes the analysis of which process positively or negatively impacts on the subsequent stages, thereby enhancing overall efficiency;

- Optimization of Resource Utilization: Facilitates the optimization of roundwood use and its transformation settings based on quality parameters (e.g. differentiate the use of logs according to their knottiness or adjust the drying kiln settings according to the expected moisture content of the roundwood according to geographical provenance);

- End-to-End Linkage: Establishing a robust linkage between the final timber product (or its components), the original tree(s), and the whole set of processes that compose the value chain from stump to artifact. This holistic linkage enhances the transparency and accountability across the entire production cycle;

- Environmental analysis: the detailed forensic analysis of timber anatomy, performed by the sawmill for maximizing sawnwood yield, linked with the knowledge of the specific origin of the tree can provide a higher understanding of the reaction of forests to natural factors and silviculture.

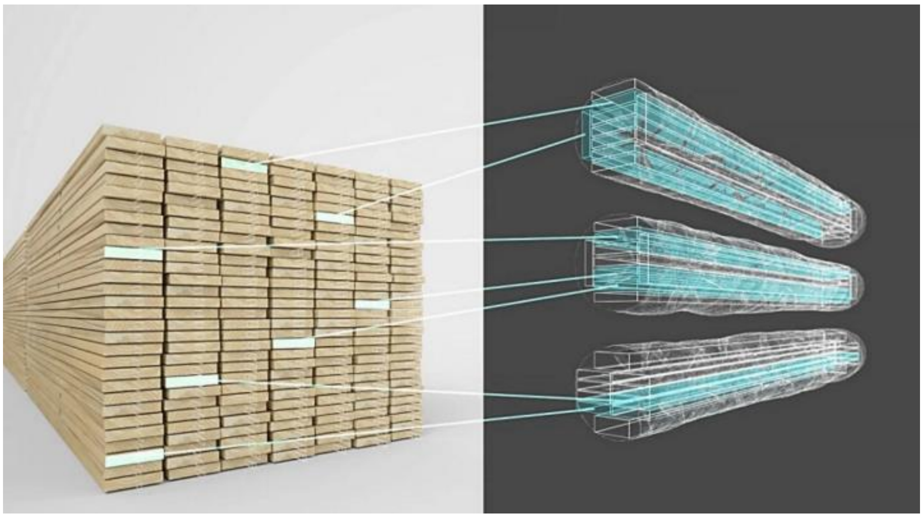

Figure 3: Traceability of boards with fingerprinting techniques (source Microtec)

Potential market

The European Sawmill Association (EOS), representing roughly 77% of the EU industrial sector, gathers about 35,000 sawmills. Overall, for the whole EU, this figure exceeds 42,000 sawmills. Out of these, any sawmill of medium to large size may benefit from the integration of this control and traceability system, providing a large plateau of potential users for this technology.

Smaller industrial facilities may not have the minimal turnover to pay back the investment of such equipment, but specific cases with high quality products may still be capable to pay back the investment in sawmill sensors.

The potential work frame is even wider if considered the sawmilling industry worldwide.

KER 3 - On board LiDAR scanning for value recovery optimization and forest inventory

Brief description

The development of LiDAR technology allows a growing application of machine-based vision in a plethora of applications. The idea to adopt such sensors on forest machines is not new. Several research use LiDAR sensors to facilitate autonomous driving (similarly to the automotive sector, but in a much more challenging environment)[1],

[1] Nakazawa M. et al. "Development of an automatic driving forwarder using in combination with lidar-slam and gnss." 55th International Symposium on Forestry Mechanization (FORMEC) and 7th Forest Engineering Conference. Florence, Italy 2023

detect soil/road damages[2] or support operators when thinning[3]. The specific application in SINTETIC is similar to the former but providing a rather different set of services. Namely, the point cloud generated by the sensor will be used in a two-staged process:

1. BUCKING Focusing on the trees being harvested, LiDAR technology will be used to characterize the commercial stem and crown of each tree, providing real time bucking suggestions to the operator. This will allow to maximize the yield of high value roundwood assortments or to fulfil the specific product demands of the end-users. In both cases, the service is meant to increase the economic value of the processing operation.
   In addition to identifying quality parameters for optimal bucking (e.g., taper, straightness, branchiness), the data will enable the segregation of logs based on their position on the standing tree. This information is valuable to certain industries, as different sections of the trunk exhibit varying qualities, and their value can be maximized through specific applications or cutting patterns.The order of the logs as corresponding to the standing trunk is an information provided by the standard StanForD data. Thanks to the marking system (KER 1) this information can be transmitted to the sawmill and valorised. Yet, the LiDAR can include further valuable information, for instance further segregating logs produced from branchless areas or belonging to the living or dead crown areas, all featuring different timber technologic properties.

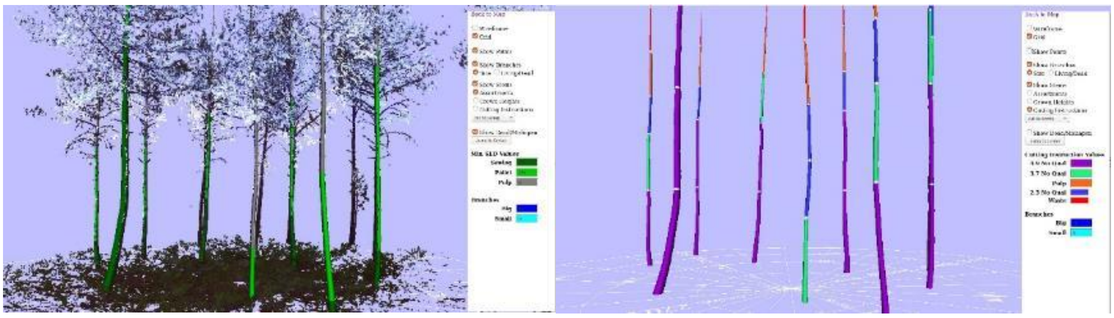

Figure 4: Example of LiDAR detection and elaboration with stem and crown detection (left) and bucking suggestions for maximum value recovery (right). (Source: Treemetrics)

2. INVENTORY When the harvester is deployed in a final felling (clearcuts), this process is the unique service provided. But in case of a thinning or any type of shelterwood cutting, the LiDAR will be used to generate a cloud point of the remaining trees. This info is provided at no cost, since the harvester/LiDAR combination survey is paid by the timber produced and the bucking optimization accrued. Yet, this valuable information can support more accurate modelling of the remaining trees, forecast its development, assess carbon credit estimate, and permit preventive measures against possible wind or snow damages highlighted by the data post processing.

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[2] https://doi.org/10.1080/14942119.2018.1419677

[3] Pohjala et al. "Assisting harvester operator with real-time mobile laser scanning system in controlling harvesting quality in thinning stand." 55th International Symposium on Forestry Mechanization (FORMEC) and 7th Forest Engineering Conference. Florence, Italy 2023

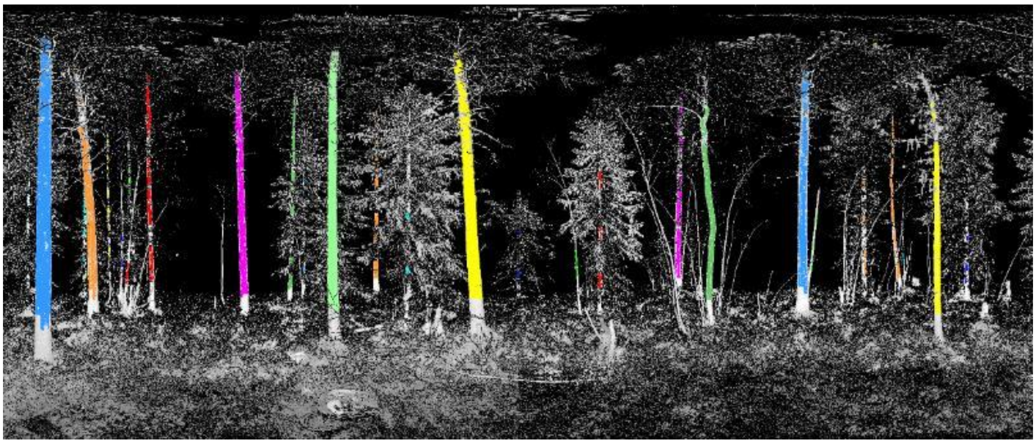

Figure 5: Example of LiDAR cloud point elaboration to characterize a forest stand (source: Treemetrics)

Potential market

In the EU, the forestry and logging sector employed about 473,100 persons in 2021[4]. No official figures are provided regarding the number of Cut-To-Length (CTL) harvesters presently operating in Europe. A study performed by Asikainen et al. (2011) forecasted for a medium mobilization scenario about 18,600 units required to meet the timber and biomass demand of the EU's wood-based industries. Additionally, most of the harvesters used worldwide are manufactured in Europe. By adopting the LiDAR optimization as a standard or as a given option for the new models, the above figure could be significantly increased.

KER 4 – Smartphone APP for forest inventory and timber measurement

Brief description

The smartphone APP provides several services based on the grid cloud point generated by the inbuilt LiDAR sensor of the iPhone 12 Pro and newer Pro versions as well as iPad Pro models. The services will range from digital forest inventory to reporting harvesting operations with digital data in StanForD format. The former is already a commercial service provided by the partner Arboreal (ARBO) in collaboration with Treemetrics (TREE). It allows to measure diameter at breast height (DBH), tree height, some stem characteristics (up to 5 m height approximately), position of the tree and other parameters generating a plot digital report.

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[4] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Forests,_forestry_and_logging

Figure 6: IOS application for forest inventory (source: Arboreal)

In the frame of SINTETIC the following services will be integrated with the APP:

- Digital marking of standing trees with RFID, interfacing the smartphone with RFID reader in combination with the SmartNail and LogRay UHF RFID tags developed by SIMTRONA (SIMTRO);
- Bucking suggestions for maximum value recovery of the felled tree (based on the LiDAR scanning of the whole stem once on the ground);
- Measurement of diameter and length of each log;
- Marking of logs with RFID and possible retrieval of its ID at any point of the value chain (for manual systems). Also, ID retrieval of the Otmetka's punched mark via camera image will be developed and tested;
- Measurement of timber modulus of elasticity interfacing the APP with the Hitman 220 sensor (the smartphone provides the length value needed by the sensor, which returns the elaborated quality value);
- Manual interface to add further information on the site/tree/logs;
- Transmission of all data to the central Geodatabase in the same StanForD format used by forest harvesters.

Potential market

The APP has a widespread potential market application in the EU and beyond, being most promising the forest sectors which presently feature a lower level of development (and thus more room for improvement). For instance, its potential is particularly evident in combination with the ForestSharing service provided by Bluebiloba (BLUEB). ForestSharing is a platform designed to aggregate fragmented forest ownership and facilitate its active management under a unique coordination. The deployment of simple but effective digital tools to generate homogeneous forest inventories will facilitate the management of small forest plots. Additionally, the possibility to follow in real time the progress of forest operations and to mark each product accrued allows for a precise accounting of share revenue of individual owners (even in case of aggregated forest harvesting) and an accurate carbon credits accounting.

KER 5 - Illegal logging satellite detection

Brief description

The service will be based both on satellite and ground data to provide an early alert system for automatic illegal logging detection. Remote identification of illegal logging operations in the EU is generally challenged by the low intensity (no large clearcuts) which produces little signal to be perceived by statistical models. The basic idea is to use a Machine learning technique to develop a parametric harmonic regression function of the Normalized Difference Vegetation Index (NDVI) obtained from observations acquired by the Sentinel 2 satellite, combined with Sentinel 1 data. This will allow to detect and analyse even small variations induced by the illegal cut and assess whether these variations are consistent with the frequencies and amplitudes assumed by the function in the same seasons in different years.

Forest machinery and chainsaw operators will automatically provide ground data in Standard for Forest machine Data and Communication (StanForD) digital format through KERs 2 and 4. This data is provided in real time or, if no mobile data coverage is available in the harvest site, on daily basis. It will report information such as the number of trees, their size and position as well as the overall harvested area in each site (plus additional details). It will be used in the first stage to train and validate the satellite detection system in the areas with expected land cover changes. In the second stage, this info will be used to filter out expected and legal forest land cover changes in areas with ongoing harvesting operations, drawing the attention of law-enforcing authorities to the unexpected changes and limiting false alerts.

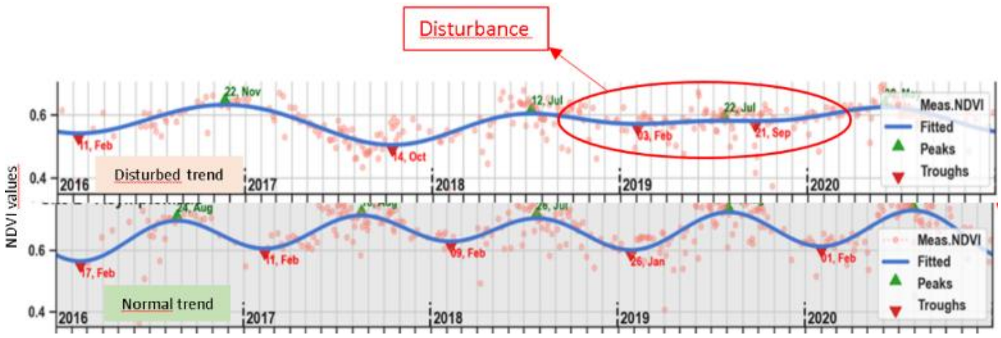

Figure 7: Harmonic regression model applied to single pixel for the automatic identification of forest cover disturbances based on satellite data(source: CNR)

Potential market

This KER is not intended as a marketable product *per-se*. The overall detection system is designed to be a free-access algorithm (upon permission of usage). Public entities and no-profit organizations would all be potentially entitled to request and adopt the system developed. Rather, it could be a further solution to promote the adoption of ground data sourcing through the traceability system (KER 1, 3 and 4).

Potential market for digitalized traceability and measurement services

European forests and timber value chain

The innovation developed by SINTETIC can be applied in any forest-based value chain, spanning from standing trees (inventory and management) to the processed timber products (sawmill industries). As such, the potential market of the system and its components includes any actively managed forest area.

Just focusing on the European Union, 39% of its total area is covered by forests accounting in 2021 for about 160 million hectares of forests (excluding other wooded land). This represents an increase of about 8 million hectares or 5.3 % since 2000 and 2.5 million hectares or 1.6 % since 2010. The stocks of timber in the EU's forests totalled an estimated 29 billion m3 (over bark) in 2021. The stocks of timber in forests increased in every Member State, giving a 31.2 % growth at the EU level in the period of 2000–2021. The increase in timber stock observed between 2000 and 2021 can be explained by the expansion of forest areas due to afforestation and natural reforestation. On average, forests of EU countries generated 146 €/ha of Gross Value Added (GVA) in 2021[5].

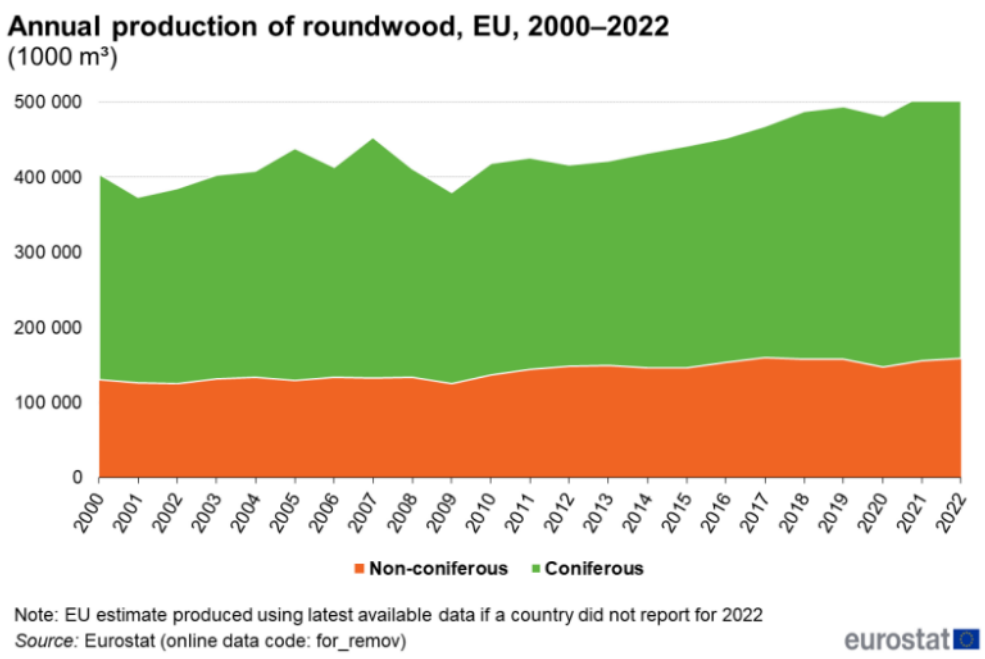

Figure 8: Roundwood production over the period 2000-2022

[5]https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Forests,_forestry_and_logging

Roundwood production (including firewood) in 2022 reached an estimated amount of 510 million m^3. This is 26 % more than at the beginning of the millennium. Except for four Member States where roundwood production decreased and further four Member States where data are unavailable, all EU countries recorded an increase in roundwood production in the period of 2000–2022 (Figure 8).

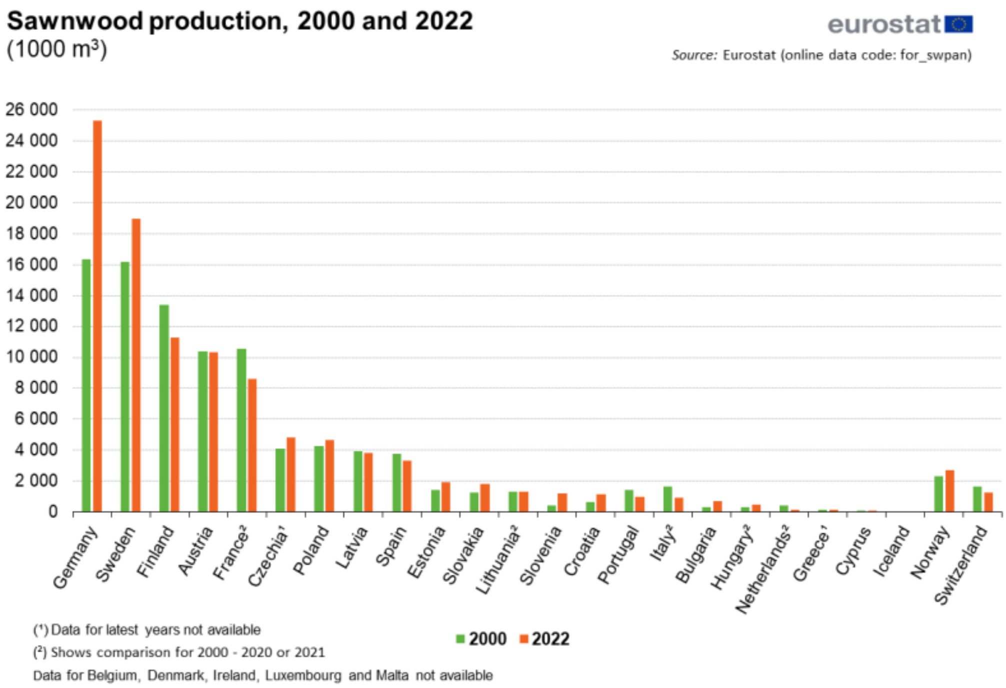

Figure 9: Compared production of sawnwood in 2000 and 2022 in EU countries.

Almost a quarter (24 %) of the EU's roundwood production in 2022 was used as fuelwood, while the remaining part was industrial roundwood mostly used for sawn wood and veneers or for pulp and paper production. Fuelwood production has slightly increased in 2022 (3.6 %), and industrial roundwood production has decreased by 1%. Trade of roundwood presents for the EU in 2022 a net balance of 12 billion m^3. Total exports have steadily increased since 2015 by 77% over the seven years, while total imports have declined since 2018 by 7.4%. The net balance is driven by the extra-EU trade of roundwood and represents 12.5 million m^3. 31% of all roundwood exports go outside the EU, whereas 16% of roundwood imports come from outside the EU.

Focusing on the raw material used by the EU industries, of the roundwood used is produced within the member states (about 80%). The remaining share is mostly imported from North and South Americas. Despite a relevant role in the past, Russia represents currently just 2% of roundwood consumption, with an import to the EU of about 10 M m^3 in 2022[6].

[6] https://blog.efi.int/does-the-eu-depend-on-russia-for-its-wood

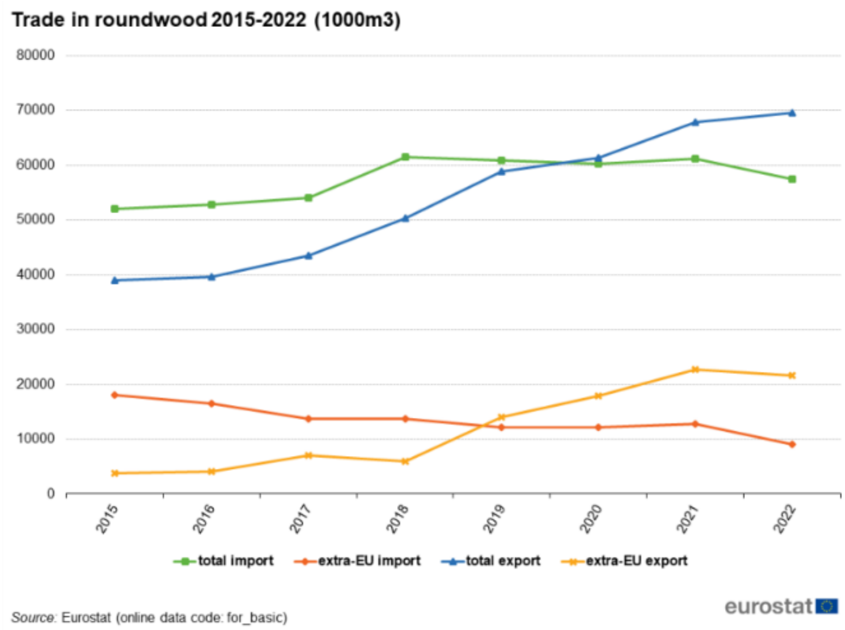

Figure 10: Import and export of roundwood in the EU

Within the EU's wood-based industries, the largest Gross Value Added (GVA) was recorded for pulp, paper and paper products manufacturing (34 % or € 46 billion). Considering the other three sectors, printing and service activities related to printing amounted to 16 % of the GVA of wood-based industries, while the manufacture of furniture and manufacturing of wood and wood products each made up between 23 % and 27 %[7].

Main economic indicators for wood-based industries, EU, 2020

Activity (NACE Rev. 2)	Number of enterprises (1 000)	Gross value added at factor cost (billion EUR)	Number of persons employed (1 000)
	2020	2020	2020
Manufacturing (NACE C)	2 063	1 881	29 401
Wood-based industries (NACE C 16+17+18.1+31)	393	136	3 093
Manufacture of wood and wood products (16)	157 du	37	912
Manufacture of pulp, paper and paper products (17)	18	46 e	620 e
Printing and service activities related to printing (18.1)	98 e	22	555
Manufacture of furniture (31)	120 u	31 e	920 e

'd' : definition differs, see metadata.
'e': estimated
'u' : low reliability.

Source: Eurostat (online data code: sbs_na_ind_r2) eurostat

Figure 11: Wood based industry, main indicators per manufacturing sector

7 https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Wood_products_-_production_and_trade

The wood-based industries employed 3.1 million persons across the EU in 2020 or 10.5 % of the manufacturing total. There were more than 900 000 persons employed within both the manufacture of wood and wood products and the manufacture of furniture, whereas an employment of 555 000 persons was recorded for printing and service activities related to printing, representing the lowest employment of the four activities. In 2021 about 473 100 people were employed in forestry and logging; a reduction of 16 % since 2000[8]. This decrease in the frame of a growing production of timber can be explained by the ageing work force in the EU counterbalanced by a growing mechanization of the forestry sector. The latter can be regarded as a particularly favourable condition to introduce innovations in terms of digital systems to generate and manage data.

EU Regulation on Deforestation-free Products (EUDR)

On the 31st of May 2023 the European Commission issued the new Regulation on Deforestation and Forest Degradation (EUDR) with the aim to reduce the impact of production and trade of timber and 6 additional main commodities with high impact on deforestation aimed at land use change (palm oil, rubber, cocoa, coffee, soy and cattle).
Focusing on the timber sector, the new regulation triggered a series of relevant changes in the forestry industry as the EUDR applies both for commodities produced outside and within the European boundaries. The regulation will enter in force on the 1st of January 2025 with a 3-year transition period for wood harvested before the EUDR enters in force. Unlike the previous EUTR, which regulated just the first introduction of the product in the European market, the EUDR applies for the whole value chain, imposing all operators and traders to comply with the requirements of the Regulation, i.e. all companies that place timber and timber products on the EU market must trace their value chain and demonstrate the application of due diligence. This implies a risk assessment analysis regarding the potential contribution to deforestation of the traded product.
Another innovation of the EUDR, particularly relevant for what concerns the outcomes of SINTETIC is the obligation to geolocalize data of the plots where the wood was harvested as well as the date or period of production. Scientific name of the trader species is also required among the minimum set of compulsory information.
This data will be part of a due diligence declaration that companies must submit via an information system set up by the European Commission to obtain permission to trade, export or import timber in the EU. The submission will be facilitated by an API, connecting the companies' database to the EU portal. Tests of the API connection is already ongoing to verify the practical feasibility and possible issues before the full application of the regulation.

Clearly, this regulation poses a challenge to companies as it will require significant investment in terms of human resources and technological update required to collect, store and verify the necessary information. The European Commission (EC) estimates that the adoption of the necessary traceability will require an investment between 3,000 and 90,000 €. A threshold that had been considered underestimated by the associations of the timber industry, and particularly challenging for smaller facilities. The EC acknowledged the risk of an excessive burden

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[8] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Forests,_forestry_and_logging

for Small Medium Enterprises (SMEs) of the sector, which might be disproportionately affected[9]. SMEs are defined by the EU recommendation 2003/361[10] upon two main factors: a) staff headcount and b) either turnover or balance sheet total.

Table 2 Factors and relative figures defining an SME

Company category	Staff headcount	Turnover	Balance sheet total
Medium-sized	< 250	≤ € 50 m	≤ € 43 m
Small	< 50	≤ € 10 m	≤ € 10 m
Micro	< 10	≤ € 2 m	≤ € 2 m

In order to facilitate the adoption of the EUDR without mayor risks for the timber sector, the EC recently clarified that the due diligence obligation for SMEs sawmills is limited to the current procedures. Namely, logs and sawn products are included in the scope of the Regulation with the CN Code 44030 and 4407 (Annex I of EUDR). The transformation of logs into-sawn products would qualify the small sawmill as an operator but, given its SME status and given that the logs are already accompanied by a DDS, they would not be obliged to submit a new DDS in the Information System pursuant to Art. 4(8). Nevertheless, they should keep the reference number of the logs' DDS and provide it to Competent Authorities upon request.

On the 11th of December 2023, the European Commission published the "Updated Frequently Asked Questions regarding the Regulation on Deforestation-free Products"[11]. Questions are divided per categories. FAQs in this category "Traceability" provide the following clarifications:

1. Collecting the geolocation coordinates of a plot of land can be done via mobile phones, handheld Global Navigation Satellite System (GNSS) devices and widespread and free-to-use digital applications (e.g. Geographic Information Systems (GIS)). These do not require mobile network coverage, only a solid GNSS signal, like those provide by Galileo. For plots of land of more than 4 hectares used for the production of commodities other than cattle, the geolocation must be provided using polygons, meaning latitude and longitude points of six decimal digits to describe the perimeter of each plot of land. For plots of land under 4 hectares, operators (and traders which are not SMEs) can use a polygon or a single point of latitude and longitude of six decimal digits to provide geolocation.
2. The Regulation requires that operators (or traders which are not SMEs) trace every relevant commodity back to its plot of land before making a relevant product available or placing it on the market, or before exporting it. The "plot of land" – the subject of geolocation under the Regulation – is defined in Article 2 (27) as "land within a single real estate property, as recognised by the law of the country of production,

9 https://environment.ec.europa.eu/system/files/2021-11/SWD_2021_326_1_EN_impact_assessment_part2_v2.pdf
10 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32003H0361
11 https://green-business.ec.europa.eu/deforestation-regulation-implementation_en

which possesses sufficiently homogeneous conditions to allow an evaluation of the aggregate level of risk of deforestation and forest degradation associated with relevant commodities produced on that land."

3. For relevant composite products, such as e.g. wooden furniture with different wood components, the operator needs to geolocate all the plots of land where relevant commodities (wood for example) used for the manufacturing process has been produced. The relevant commodities' components may be neither of unknown origin nor from areas deforested or degraded after the cut-off date.
4. Operators and traders which are not SMEs need to verify and prove that the geo-location is correct. Ensuring the truthfulness and precision of geolocation information is a crucial aspect of the responsibilities that operators and traders must fulfil. Providing incorrect geolocation details would constitute a breach of the obligations of operators (and traders that are not SMEs) under the Regulation.
5. It is the responsibility of the operator (or traders that are not SMEs) to collect the geolocation coordinates of the plots of land where the commodities were produced. If the operator cannot collect the geolocation of all plots of land contributing to a relevant product, then s/he shall not place that product on the market or export them, in accordance with Article 3 of the Regulation. Operators (and traders which are not SMEs) and enforcing authorities could cross-check the geolocation coordinates against satellite images or forest cover maps to assess if the products meet the deforestation-free requirement of the Regulation. However, the operators (and traders that are not SMEs) remain liable.
6. Operators (and traders that are not SMEs) are required to collect information on the date or time range of production under the obligations set out in Article 9 of the Regulation. This information is needed to establish whether the relevant product is deforestation-free. That is why it applies to the commodities covered by the Regulation that are placed on the market or to the commodities that are used for the production of relevant products covered by the Regulation. For commodities other than cattle, the date of production refers to the date of harvesting of the commodities, and the time range of production refers to the period/duration of the production process (for instance, in the case of timber, "time range of production" would refer to the duration of the relevant harvesting operations). N.B: information on date or time range of production of a product operators wish to place on the market or export does not need to be included in the due diligence statement, but operators are required to collect, organise, and keep it for five years (Art.9).

Although SMEs are not obligated to provide and verify information, when selling to a large enterprise, the large enterprise requires all relevant details, effectively compelling SMEs to supply the necessary information.

SINTETIC contribution to EUDR requirements

SINTETIC is a production-oriented project, where the optimization of the different steps of the value chain as well as the management of digital data provide an added value to the operators and stakeholders involved. In fact, the main ambition is to create a self-sustainable system, where the additional costs are covered by the economic benefits brought to the forest owners, harvest and logistic contractors as well as the transformation industry.

In this scenario, the environmental and social benefits foreseen as project's outcomes are provided at no additional cost for the actors of the forest and timber-based economy.

Current technologies deployed in forest value chains as potential alternative to KERs

Given the database structure provided, geolocation coordinates of the plot (and the single tree) are already included along with tree species and a plethora of additional information that may be relevant to the demonstration of due diligence and sustainable use of natural resources. The prosecution of the traceability within the industrial facility and along the transformation process from roundwood to sawnwood will allow to provide a unique tool for demonstrating the origin of the commodities (timber) used for the manufacturing process of wood-based products. The industrial sensors necessary for KER 2 are accessible just to large industrial facilities due to the investment and running costs. But the exclusion of SMEs from the complete requirements of the EUDR makes SINTETIC a comprehensive solution for all the companies obliged to fulfil the regulation's requirements.

Clearly, the management and storage (for five years) of large datasets is a challenge. Yet, the data formats selected in the project are designed to minimize its size in order to facilitate transmission (e.g. from the forest with a typical poor coverage of mobile data) and storage.

Table 3 SWOT analysis of SINTETIC in the frame of the EUDR application

SWOT	Helpful	Harmful
Internal	Strengths - Very detailed traceability, exceeding the requirements of EUDR - Includes analysis of stakeholders necessities and constrains - Designed in order to cover the traceability costs with additional added-value services	Weaknesses - Timing of service release was not conceived at project presentation stage to meet the EUDR entry in force - In some value chains with low value requirements (e.g. packaging) the single-item level traceability exceeds the EUDR requirements without providing added value.
External	Opportunities - Provides data in a unique digital format (StanForD) for all work systems, enabling standardization and integration with existing IT infrastructures	Threats - The system generates a large amount of data, particularly if the sawmill traceability is included.

Technologies for marking and tracking forest products

Certification schemes (FSC-PEFC)

Certification schemes are documental based services designed to guarantee the sustainable creation and trade of forest-based products (timber, paper, etc.). Sustainability is intended both from the environmental point of view, promoting sustainable forest management practices to limit the negative impacts of exploitation of forests and their ecosystems. The two main forest certification schemes in Europe (and worldwide) are the Forest Stewardship

Council (FSC) and the Programme for the Endorsement of the Forest Certification (PEFC). FSC was founded in 1993 as a voluntary certification for sustainable forestry, promoting environmentally sound, socially beneficial, and economically viable management of the world's forests. Nowadays, FSC has an extensive certified supply chain network, enabling connections between markets and sustainable forestry – including over 200 million hectares of forest managed according to its standards. In Europe covers more than 55 million of hectares[12]. PEFC endorses national forest certification systems developed through multi-stakeholder processes and tailored to local priorities and conditions. It works with national organizations to advance responsible forestry, allowing national structures to develop their own guidelines suited to local conditions and priorities. Over 280 million hectares of forest area are managed in compliance with PEFC's internationally accepted Sustainability Benchmarks, with 82 million of ha only in Europe[13]. The two certification schemes provide a different general approach: while the FSC sets international standards to be applied worldwide with adaptation to the local conditions, the PEFC functions as an umbrella organization endorsing regional and national forest certification systems through independent third-party certification[14].

There are some steps to follow for being certified according to forest certification schemes: first, one must contact the PEFC or FSC national offices for support, then must prepare for the audit by studying the documentation attaining to the desired certification scope (sustainable forest certification or chain of custody for products), including the use of the certification logo and trademarks. A management system in compliance with certification scheme requirements must be set up and possibly integrated into an existing system such as ISO 9001 or ISO 14001. Other passages involve the training of the employees and collaborators, and the implementation of an internal audit before arranging the Certification Body (external) audit. Finally, a PEFC/FSC-recognized Certification Body must be selected and contacted for the audit. A certificate is valid for up to five years, with annual surveillance audits. Costs of Chain of Custody certification is fixed by individual Certification Bodies, so prices may vary. Audit time depends on several variables, including company size and complexity of the Chain of Custody.

Some voices are raising against the inaccuracies of certification standards[15]. The compliance can be guaranteed only in the forest, but along the forestry–timber chain, there are discontinuities and security gaps that need to be contained using new technologies. Technical solutions are needed to collect the data required to close these gaps16.

In literature, some Authors have identified recommendations for improving forest certification impacts. Besides the enlargement of the scope of indicators under observation, data on existing indicators of forest certification impacts, like aggregate deforestation, soil erosion, worker wages should be better collected and shared. “Publicly accessible data enables systematic measurement of impacts and stronger causality claims, which can subsequently be used to strengthen the positive impacts of certification schemes” [17].

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[12] https://connect.fsc.org/impact/facts-figures

[13] https://cdn.pefc.org/pefc.pt/media/2023-05/3dabbd50-dacd-4a45-a9f2-5eba543e5a40/90be8e62-4927-5df4-a5ce-fc44a7f66228.pdf

[14] *https://doi.org/10.3390/f11080863*

[15] https://www.theguardian.com/sustainable-business/tracking-timber-new-technology-supply-chain

[16] https://doi.org/10.3390/f14091718

[17] https://doi.org/10.1016/j.cosust.2018.06.001

Nevertheless, this may have a detrimental impact on the economic viability of certification, defined as the capacity of the certification process to sustain itself by keeping costs lower than benefits from the social, economic or political point of view. According to a review analysis[18], economic viability is achieved in no more than half of the cases, and it is particularly challenging in Europe and North America, which represent most of the certified forests.

Certification schemes and EUDR

Building on the widespread service already provided and the high visibility throughout the forest sector, the two organizations are developing new tools to cope with the requirements set by the EUDR in the European market of timber products.

As an example, FSC is releasing several digital services built on top of the common normative framework set up for certification purposes. These web-based services will interface with the EU portal via API constituting a due diligence reporting system. Through this, the users will be able to access and deploy several services, such as the database for species recognition, the risk assessment library, the plot information (geolocation and optionally cadastral) generating digital audit reports (figure 12).

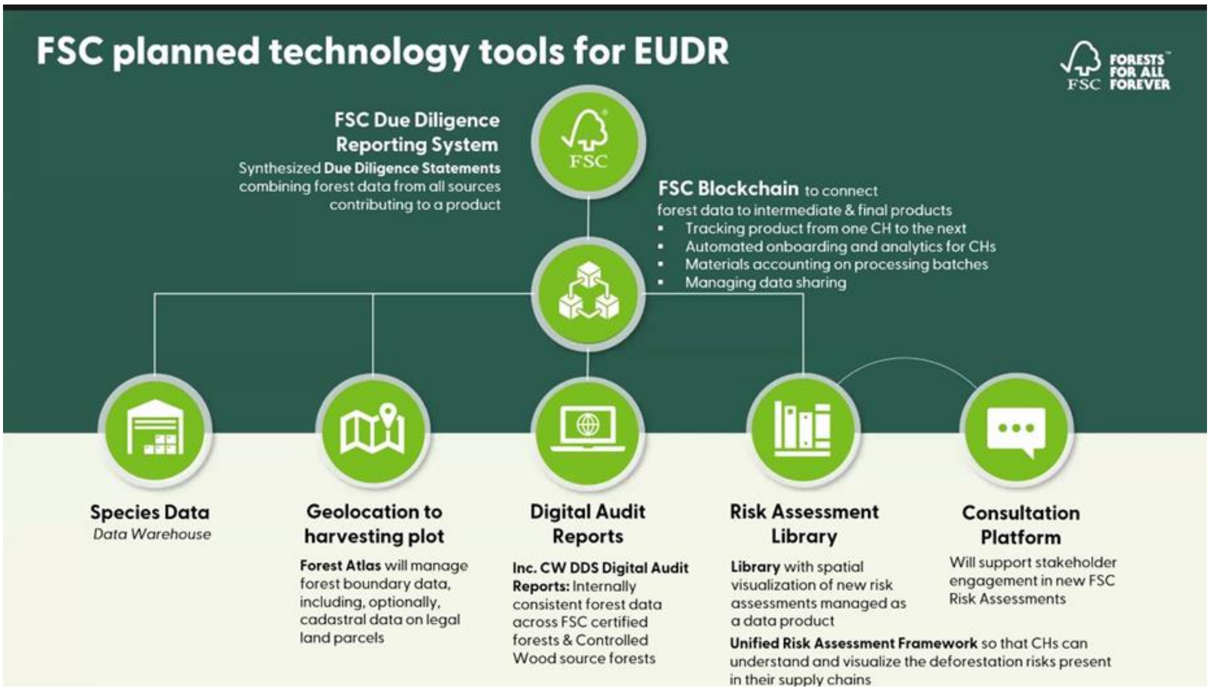

Figure 12: Wood based industry, main indicators per manufacturing sector (source: FSC)

Data transfer among these services is guaranteed through a "blockchain tool" that it will be officially launched within the year 2024. This service will systematically transform the verification, data enrichment, and connectivity of claims about FSC-certified products throughout supply chains.

According to FSC, the FSC Blockchain will assist companies by:

- Verifying the certification status of suppliers at the point of transaction.
- Generating verified and traceable claims regarding products traded between themselves and trading partners.
- Passing relevant data about the raw materials comprising FSC-certified products, including information such as geo-location of origin, time of harvest, species, product groups, and other essential data points.

This tool will include an online platform where operators can upload the traceability information as requested by the EUDR, share them downstream in the value chain and evaluate possible risk. The latter will use as input the georeferenced position of the specific plot of land returning information regarding the associated risks and providing a set of "mitigation measures" (recommended or mandatory). This risk assessment will be based on an analysis of countries benchmarking commissioned by the EU and a second independent ranking done directly by FSC.

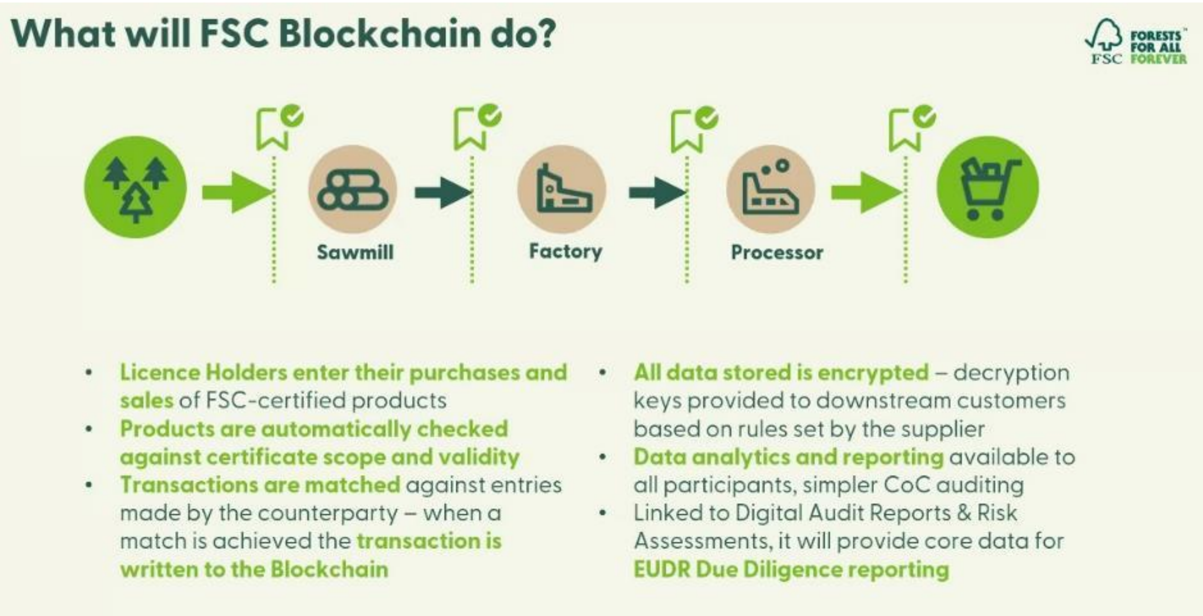

Figure 13: Data flow and scope of the FSC Blockchain (source: FSC)

The overall system provides a valuable service to the operators of the value chain, ranging from forest owners to traders and industry. Being necessarily based on documental proof of the provenance of products it has limitations to manage complex scenarios where the production steps detour from the common workflow. This may be the case of the recovery of salvage wood (e.g., large windthrown areas), or complex value chains based on one or more intermediate yards and storage areas. In this case, the lack of a technology capable to mark each single product (log) providing a digital ID for the system makes unreliable an effective certification of the provenance of the specific lot of timber, which can be guaranteed, at the best, just at wider scale (e.g. at basin level).

Current technologies for marking and tracing timber products in forest and sawmill

Marking of single trees and logs is a relatively common practice worldwide. In this frame, it is important to distinguish marking of standing trees and marking of logs, as these two operations are not necessarily linked, and are often carried out for different reasons.

The most common application is the identification of standing trees, particularly used in non-industrial silviculture. It is primarily intended as a forest management tool, facilitating the achievement of the given silviculture goals. More in detail, the forester marks the trees to be felled (or those to be retained) to guide the harvesting operations and secure that the overall aim of the intervention is achieved (e.g., to facilitate natural regeneration). For this purpose, marking is just executed with colour or debarking a spot on the stem (Figure 14). The same operation can be used to control the harvesting operations, limiting illegal logging of individual trees in excess to the planned quantity. In this case the debarking mark is executed with a brand hammer, featuring a unique mark to identify the forester responsible for the selection. The mark is applied on the debarked wood both on the stem and on the stump, the latter remains on the site after harvesting as a proof that only the marked trees had been felled. In none of the above cases the mark carries specific information related to the single tree, being merely a control or management system at the stand level.
Marking of standing trees can also be done for non-productive purposes, such as inventory of parks or monumental individuals. In this case, requiring a long-term permanence of the mark, plastic or metal labels as well as RFID tags are commonly deployed. Information related to the specific tree can be linked to the mark, for instance facilitating the retrieval in an inventory system or an informative database (e.g., providing species, age and other details in an arboretum)

Figure 14: Trees marked for felling in Alpine close-to-nature forestry (left). Marking is performed with several alternative solutions (right): colour spray, a debarked spot (the brand hammer is visible on top-right) and RFID tags (black spot into the debarked spot (source: Picchi, CNR-IBE)

Roundwood identification (marking of single logs) is generally performed for commercial or traceability purposes (often both). In this case, the whole value chain must be involved, at least from the forest (roadside) to mill for the management and valorisation of the tracking information. This practice is less common than the marking of standing trees being generally relegated to local value chain, pivoting on the procurement area of specific timber consumers or the production of specific high-value timber products. This may be the case of the Vosges in France, where large diameter timber is marked individually, or the high-value Croatian oak products. Yet, there are cases of adopter with wider scope, such as the Polish State Forests which managing about 7.5 million hectares marks about 3 million logs per year.

The simplest marking system can be a logo painted with canvas (picture 15, left). Yet, when the action entails a commercial value, technologies capable of identifying the single log or at least the lot are applied. Among these, the most traditional are brands or codes punched directly on the timber (picture 15, right).

Figure 15: Log stack marked with colour (left) and brand hammers with variable code to identify the timber (right) (pictures: Picchi; right source: Musée des Métiers du Bois)

Nowadays, in most of cases the punching marks had been replaced by the "plaquettes". These are plastic tags designed to be applied on the cross section of the logs with a special hammer. During manufacture it is possible to print several information on the flat surface of the tag. Generally, they feature a progressive numbering, but the reported information can be customized e.g., including a code identifying the company or the forester marking the logs. Besides the alphanumeric characters, a barcode or QR code reporting the same information can be included, disclosing the possibility to acquire the ID of the plaquette (and thus the log) with a smartphone or a barcode reader. At present, plastic plaquettes are the most advanced system for log marking actually used in commercial operations at relatively large scale. Although they could potentially allow for a certain degree of automation, they are mostly used on a local scale (e.g. the procurement area of a given sawmill requiring their use for identification or control of incoming timber) and with a limited level of digitalization of the data acquisition and exchange.

Very few studies address the application of this technology in forest value chains[19], and none of them provides an analysis of costs or spread over the EU forestry sector. According to the commercial sites of the manufacturers and resellers, plastic tags feature a unitary cost of about 0.14 €[20], which is approximately half of the price of the simpler RFID tag deployed for the same timber marking application[21].

As a further integration, considering the technologies under development and/or in testing phase, the Deliverable 1.1 provides an extensive overview of all the alternatives potentially applicable for the traceability of timber products.

In the frame of the same review analysis, no alternatives were identified for the traceability of timber products spanning from roundwood to boards within the sawmill.

Figure 16: Hammer and magazine for plastic plaquettes (left) and operator measuring a log marked with a plaquette (right) (pictures: Picchi, CNR-IBE)

[19] Étude de la durabilité des plaquettes de marquage pour grumes en plastique" Jones et al. (2010)
Effets de l'identification des grumes sur la traçabilité et la gestion des stocks de bois en France" Jean-Luc Doudet et al. (2018)

[20] https://le-besson.com/Plaquette-d-identification-avec-Marquage-Laser-1-numero-2-lignes-de-texte-1000-pieces--0014455.html

[21] https://doi.org/10.3390/f11020150

SINTETIC contribution to track and trace forest products

SINTETIC will introduce a unique system for digital tracking and tracing of forest products. With a seamless data flow from the standing tree to the final industrial product (board or composite timber product) it will provide a powerful management and optimization tool to all the actors of the forest value chain. The interconnection of any digital data source, provided by inventory or process sources, will enable a plethora of possible optimization services. The use of a combination of physical marking systems will enable automatic, error-free and fast identification of each item, simplifying measurements and transactions. By including additional quality data the industrial processes, particularly those based on high quality thresholds, will be further optimized generating an added value that will cover all or part of the additional costs required to deploy the marking and traceability system.

Table 4 SWOT analysis of SINTETIC for product marking and tracing applications

SWOT	Helpful	Harmful
Internal	<u>Strengths</u> - Technology upgrade allowing bulk and automated reading of the IDs in marked products - Integration of volume assortment type and quality data - Normal and mechanized marking are possible depending on the user needs	<u>Weaknesses</u> - Higher cost of technology and expendable parts (tags).
External	<u>Opportunities</u> - Provides data in a unique digital format (StanForD) for all work systems, enabling standardization and integration with existing IT infrastructures	<u>Threats</u> - Needs integration among several stakeholders, in some cases already implementing a different marking and tracing system - Additional costs of the systema and -possibly-lower level of productivity need to be carefully calculated and fairly shared among the value chain actors.

Technologies for value recovery and forest inventory

In the realm of forestry management, the increasing reliance on technology has paved the way for innovative solutions that streamline processes and enhance efficiency and precision. Forest inventory, forecast of timber assortments and value estimates are an essential part of the productive management of forests. Additionally, the integration of digital technologies in harvesting operations disclosed the possibility to increase the yield and value of timber assortments from the same resource. Building on this background, SINTETIC will bring a contribution to further optimize the estimate and production of timber assortments.

Fully mechanized harvesting

Figure 17: Single grip processor with feeding rollers (left) and stroke single grip processor delimbing a tree (right) (pictures: Picchi, CNR-IBE)

Mechanized harvesting can be performed with several alternative systems. In Europe, the dominant harvesting system is the Cut-To-Length (CTL). This is based on the use of single-grip timber processors which perform the tasks of tree felling, delimbing and crosscutting. These operations are supported by an onboard bucking computer that manages the operations and provides a certain degree of automation of the different processes (e.g., delimbing for a predefined length of the trunk). The bucking computers record a large set of data of the tree and stems produced, basically leveraging on two main sensors that provide diameter of the grabbed log (based on the mutual position of the delimbing arms or the rollers) and the length of the trunk that has moved through the processor. The figures provided are used for several services, such as:

- Perform crosscut at pre-defined length according to the desired timber assortments
- Discriminate timber assortments based on length and top-end diameters
- Measure the volume of each log
- Provide digital cutting reports

The latter information enables monitoring of the work progress, pace and yield of products. In Scandinavia it is also used for directly invoicing the produced assortments by sharing the digital data with the end user or the roundwood. For this purpose, the Swedish Skogforsk developed a digital standard format for processor data. This standard, named StanForD and StanForD 2010, gathers a plethora of data regarding the prime mover (harvester) and the timber produced[22]. Among other parameters, the files include the following:

- DBH of each felled tree
- Diameters at every 10 cm and length of each log (characterizing the assortments)
- Number of logs produced by each tree
- Link the digital ID of each tree with the relative logs
- Timestamp of each main operation (felling, crosscutting)

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[22] https://www.skogforsk.se/english/projects/stanford/stanford-2010/

- GNSS position of the tree felled (assumed to be as also the approximate position of the resulting logs)

For a reliable application of these data, the processor head should be constantly calibrated. In the countries deploying StanForD data for timber invoicing, specific calibration protocols are distributed among the harvest contractors.

The availability of large datasets of processed trees makes possible the development of statistical models for the estimate of the optimal bucking of trees based on the diameter measured in the felling process. Most machine manufacturers develop their proprietary models, which often feature adaptability algorithms to adjust the bucking instructions to the specific characteristics of the trunks in the forest stand being harvested. This enables the machine to perform bucking of trunks as an automatic process, leading to a significant increase in productivity while maintaining a value recovery similar or superior to the performance of an expert operator [23].

Figure 18: Forest harvester deployed to fell and process trees (left) map visualization of the georeferenced data reported in StanForD files regarding the position of the felled trees (right) (pictures: Picchi, CNR-IBE and Alcoverro, CTFC)

SINTETIC contribution to enhance value recovery and inventory of forest resources in mechanized systems

The LiDAR developed by SINTETIC (KER3) will enhance the value recovery by assessing the characteristics of the stem before felling. Factors like taper, sweep and crown height can potentially be measured at tree level. Including these factors in the bucking suggestion would allow to further improve the bucking process and the yield of high-quality timber assortments.

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[23] https://doi.org/10.14214/sf.9947

Additionally, SINTETIC will base all harvest data on the same StanForD format, while adding supplementary information such as the ID of each log based on physical marking (RFID or punched mark), which enables retrieving the identity of the roundwood at any step of the value chain. This will disclose the potential of StanForD data to fulfill traceability services, as requested by the EUDR. Additional information will include quality parameters as measured by the timber sensors (e.g., sweep, taper, stiffness, etc.). This will provide a further added value to the end users, optimizing logistics and transformation of the timber.

Table 5 SWOT analysis of SINTETIC in mechanized operations

SWOT	Helpful	Harmful
Internal	Strengths - Capacity to capture quality details presently not considered in automatic bucking - Potential for continuous and highly detail bucking model improvement based on the feedback of sawmill sensors	Weaknesses - Integration of real-time stem characterization and inclusion of resulting elaboration in bucking suggestions is very challenging - Addition of LiDAR sensor may exceedingly increase the cost of the harvester
External	Opportunities - Provides data in a unique digital format (StanForD) for all work systems, enabling standardization and integration with existing IT infrastructures	Threats - LiDAR based bucking solution will find resistance of machine manufactures to install on their products as it competes with their proprietary bucking solution

Manual inventory and harvesting systems

Forest inventory is probably the sector with the highest degree of digitalization in the timber value chain. Data from remote sensors, such as satellite images, airborne and ground LiDAR increasingly integrate the traditional systems based on manual measurements (relascope, calliper) and dendrometry functions. Typically, given the level of detail provided, digital data is used at large scale, with manual ground truthing at sub-sample level.

In recent years, the increasing reliance on technology has paved the way for innovative solutions that streamline processes and enhance traceability. One such solution is the Mobile Application for Forest Measurement and Traceability, where examples of companies and services like Arboreal and Trestima illustrate the transformative potential of these applications based on APP installed on smartphone. Several IT companies provide services and APPs for forest management, forest inventory, and measurement of standing trees or piled timber. As such, competition may come from existing forestry software solutions, but the unique features and user-friendly interface of the proposed mobile application can differentiate the solution developed by SINTETIC in the market, including:

- Tree Measurement Using Sensors: Integration of cutting-edge sensor technology allows for precise and automated measurements of tree dimensions, including height and diameter (e.g. Arboreal App).
- Real-Time Data Collection: Mobile application can enable real-time data collection in the field, reducing the time lag between measurements and decision-making.

- Traceability and Transparency: The applications ensure traceability by linking each measurement to specific geographic coordinates, unique ID and/or timestamps, addressing concerns related to transparency and sustainable forestry practices.
- Integration with GIS, Inventory analysis and Bucking simulators: Integration with GIS and mapping functionalities enhances spatial visualization, providing a comprehensive view of the forest landscape. Online analytics for inventory analysis and bucking simulators are also a key feature to provide a seamless added value to the field measurements.

Among the competitors studied there is not any commercial solution supporting tree level traceably with RFID or other system that it is not only based in tree spatial coordinates. Some specific technologies and solutions that might be relevant competitors or counterparts in this domain, include:

- Trestima focuses on real-time data collection and decision support in forestry. Trestima can record the tree coordinates and tree ID. Other dedicated traceability features such as RFID are not supported by Trestima.
- Forest Metrix: Forest Metrix is a mobile forestry software app for timber cruising, forestry plans, mensuration, and forest inventory. Forest Metrix offers a mobile solution for forest inventory and data collection, aiding in the traceability of forestry resources via tree coordinates and tree ID.
- Forest2Market: Offers an application for collecting, analyzing, and managing timberland data.
- Trimble Forestry Solutions: Trimble provides forestry solutions for inventory management, traceability, and harvesting optimization. Trimble Forestry can record the tree coordinates and tree ID. Other dedicated traceability features such as RFID are not supported by Trimble Forestry.
- TimberOps: TimberOps is a forestry management application that includes mobile data collection tools, GIS mapping, and analysis features. It aims to streamline forestry operations and decision-making.
- SilviaTerra's Plot Hound: SilviaTerra's Plot Hound is designed for mobile forest inventory. It provides tools for data collection and integrates with the larger SilviaTerra platform for analytics and reporting.

Besides the development of applications dedicated to forest measurement and inventory, other valuable services can be included. An example is provided by the bucking APP developed by the EU project Tech4Effect[24]. This supports the chainsaw operator to value-optimize the bucking scheme of a given tree. Being based on Android, all input measurements are manually done and typed on the smartphone.

[24] https://www.tech4effect.eu/results/bucking-app/

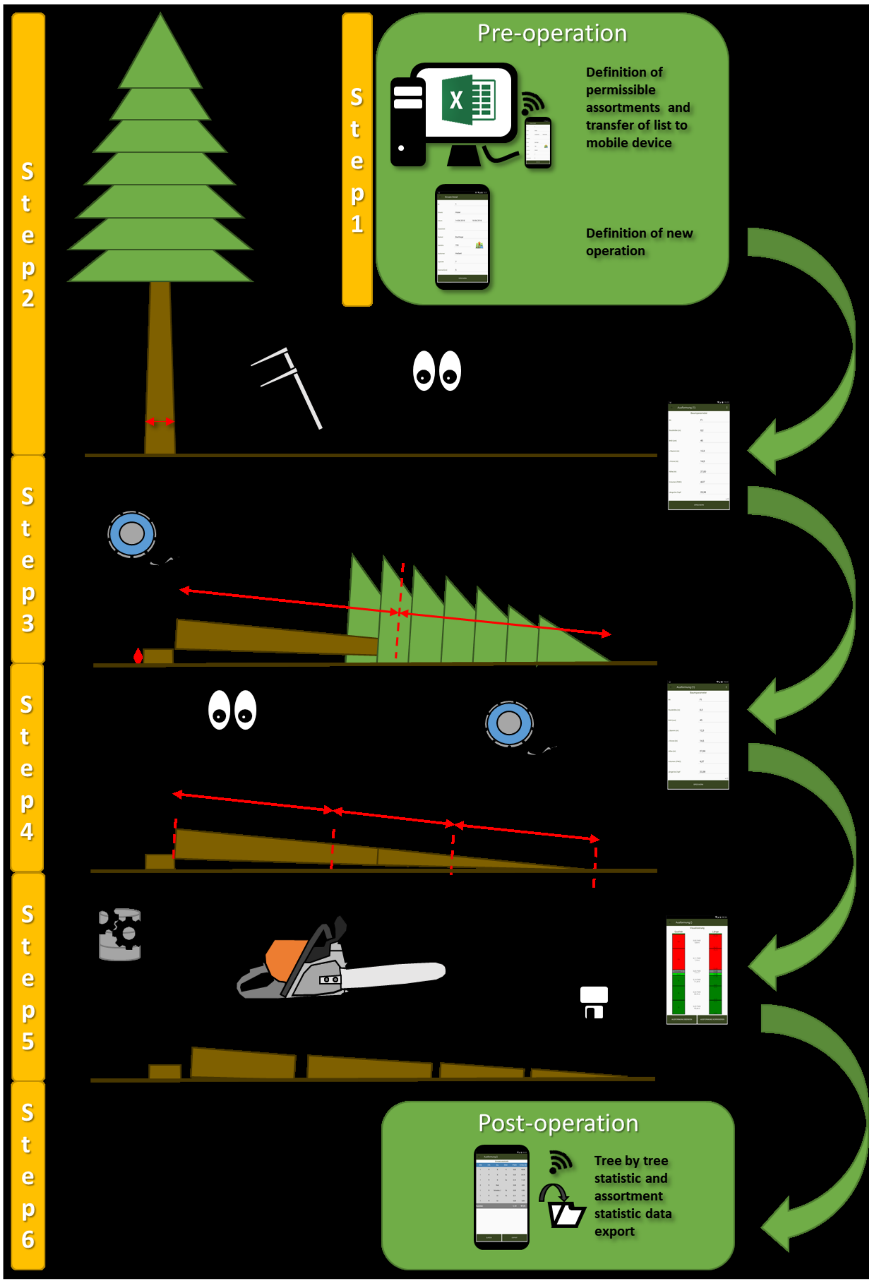

Figure 19: Process schema of the T4E bucking APP (source: www.tech4effect.eu/results/bucking-app/)

SINTETIC contribution in manual inventory and bucking operations

SINTETIC's commercial products will provide several advances to the current state of the art of instruments and services.

The mobile APP (KER4) will enable a homogeneous digital forest inventory also in small stands, supporting the standardization of inventory information. In this frame, it will be particularly relevant in synergy with the ForestSharing platform, dedicated to aggregate and manage fragmented forest properties. In fact, the availability of a low-cost and easily replicable inventory system will stimulate resource inventory and the consequent management. Thanks to the availability of a LiDAR sensor on several IOS-based smartphones, the application actually collects measurements, integrating the function of the competitors APPs and these of the dendrometry instruments. The possibility to use the traceability system (KER1) to interrelate the inventory data - including estimates of volume, value and assortments - with the sawmill digital data provided by the sawmill sensors (KER2) will provide a unique tool to further calibrate and validate the forest inventories leading to a higher level of precision.

The same algorithms used for standing tree measurement will be deployed by the chainsaw operator to measure diameters and length of each log produced from the felled tree. The use of RFIDs on each element of the production process (tree>logs) will enable a physical and digital connection among the original tree and the assortments obtained. Additionally, the app will suggest optimal bucking based on actual measurements of the stem, providing a higher level of precision. As a further improvement, the APP will share via mobile connection all collected data in StanForD format, homogeneous with the data already provided by forest harvesters. This will enable an unprecedented level of interoperability of data provided by different forest harvesting systems.

Table 6 SWOT analysis of SINTETIC in manual operations

SWOT	Helpful	Harmful
Internal	Strengths - Higher precision thanks to in-built LiDAR of IOS-based smartphones - Possibility to increase the precision value and volume assessment forecast based on the feedback from sawmill data	Weaknesses - Based on more expensive devices
External	Opportunities - Very simple and accessible inventory tool, coupled with a timber measurement system. - Output in StanForD format of bucking allows for seamless integration with current IT systems of industry - Unique application providing a range of services (forest inventory, marking and tracing trees and logs, roundwood measurement)	Threats - Manual inventory will face competition of a plethora of APPs with same scope and based on the more common Android OS (even if the latter provides less precision).

Technologies for illegal logging control

Illegal logging is a world-wide crime. In some countries it can represent up to 90% of timber exports. Besides its dramatic impact on the ecosystems and local community, it causes to the international community an overall cost estimated between 30 and 100 billion Euros[25]. Criminological theories suggest intervention mechanisms aimed at preventing or at least limit illegal logging of forests. These mechanisms include remote sensing control of forested areas, adoption of wood tracking technologies, and independent certification. These should be applied in synergy with an increased forestry law enforcement and an active forest management[26]. In fact, the use of remote sensing to explore illegally logged areas is not new; however, there are several limitations to the efficient identification of problem areas (i.e. hot spots) and the prompt information of forestry law enforcement patrols. This is due to the coexistence in a same territory of legal and illegal harvest operations, as well as natural events (e.g., landslides), all causing similar variations in the forest cover response to satellite analysis (e.g. NDVI variations). In addition to territorial monitoring, securing commercial transactions of timber products with traceability systems can further reduce the impact of illegal timber trade (hence its production). This can be achieved with include timber tracking technologies coupled with sophisticated chain of custody (CoC) systems. It is important to note that while these procedures seem straightforward, the strict adherence to designing and implementing simple uniform rules, regulations, and procedures allows limited opportunity for fraud, corruption, and other illicit activities that facilitate the legitimization of illegally logged timber into the legal supply chain. Thus, these chain of custody systems are needed to prevent operators from combining illegally harvested or sourced logs with others of legal origin (log laundering).

In Europe, several countries face the issue of illegal harvesting of forest resources to a variable degree. Among these, Romania attracted public attention due to reiterated cases of violence against foresters and law enforcement personnel and extended damage to Natura 2000 areas[27]. In the case of Romania, the National Government developed and established a wood traceability system named Sistemul informaţional integrat de urmărire a materialelor lemnoase (The integrated informational system for wood traceability) - SUMAL 2.0[28]. It is a control service extended at country scale and based on a centralized online platform interfaced with several applications for smartphones.

Applications of SUMAL 2.0:

a) SUMAL 2.0 for forest management planning
b) SUMAL 2.0 for forest districts

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27 https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.euronatur.org/fileadmin/docs/Urwald-Kampagne_Rumaenien/Investigation_of_Romanian_forests_in_Natura_2000_sites.pdf&ved=2ahUKEwiThdCYov6GAxWGg_0HHQ-SANAQFnoECBIQAQ&usg=AOvVaw1WK5Ktnio-g3PCEaEl0ywh

28 http://www.mmediu.ro/app/webroot/uploads/files/HOT%C4%82R%C3%82RE%20nr.%20497%20din%2025%20iunie%202020.pdf

c) SUMAL 2.0 for companies – electronic registry
d) SUMAL 2.0 for waybills
e) SUMAL 2.0 for control of timber trucks (citizen driven)
f) SUMAL 2.0 Super administrator
g) SUMAL 2.0 Forest Guard
h) SUMAL 2.0 Forest Inspector
i) SUMAL 2.0 SNEICS

The main features of the system are as follows:

- Works mainly based on manual measurements of the wood that are the basis for reporting in the platform;
- For transportation, in most cases it requires to take pictures of the truck from the front, sideway, back of the truck (the picture should cover all the load), as well as the odometer before transportation (in the cabin) - SUMAL 2.0 Waybills;
- Connects to the GSM network and when there is no available, the transporter needs to keep the number of registration printed until the truck reaches the GSM network;
- Once the transporter reaches to the beneficiary, the beneficiary takes the information by SUMAL 2.0 for companies and verifies the information, then he has two options: to accept or to reject the transport. If accepted, the transport is considered finished;
- There are timelines enforced for a transportation depending on the distance of delivery;
- The system of measurement is based on tolerances;
- It is based on GPS tracking.

A similar product had been released by a large private industry in Romania and deployed on a voluntary basis. The tracking system, named TimFlow[29], has features comparable with SUMAL 2.0:

- GPS tracking;
- Synchronization with a data server (every 30 seconds);
- Control of the sourcing at the factory gate: loading place and the route of the truck;
- Automated wood measurement in the factory;
- Public availability of the data within 96 hours (requires an account);
- Requires picture taking.

SINTETIC contribution to illegal logging control

The project will enable an unprecedent tool for validation and calibration of the satellite data. This will be based on the ground data provided by mechanized and manual systems of KER1. Coupled with the single-item traceability of the timber products sourced during the operations the system will enable a very effective control system. Law enforcement actions will be further optimized by the provision of an automatic alert system that will filter outlegal

[29] https://www.timflow.com/

forest operations (designated by active StanForD data sourced from an area with valid harvest permission) focussing the control efforts on unexpected events (natural events or criminal activities).

Table 7 SWOT analysis of SINTETIC in illegal logging control

SWOT	Helpful	Harmful
Internal	Strengths - Combination of satellite data with a large and continuous flow of ground data allows for a very detailed calibration and validation of detection algorithms.	Weaknesses - Need of data sourced from ground operations with similar aspect/characteristics as the actual illegal logging sites
External	Opportunities - Need of forest operators and local timber market to prove the legal provenance of the timber brought to the market	Threats - Willingness of operators to adopt and maintain the ground data transmission system - Possible concerns regarding privacy of operators

Potential constrains to the adoption of the Key Exploitable Results

The analysis of potential constrains (and opportunities) to the exploitation of SINTETIC's the technology

Is based on the data collected in the frame of the Deliverable 1.1 "User Requirements". The document is based on a survey conducted on different actors of the forest value chain. The interviews and questionnaires addressed the specialists and professionals, who were classified according to their role in the timber production process from forest to industry. Namely the respondents were classified as 1) foresters/forest owners, 2) harvest contractors, 3) timber industry and 4) public authorities. In spite of the "rigid" classification, several respondents covered more than a single role (e.g., a respondent could be both a forest owner and a forest contractor), providing answers with a comprehensive vision of the application of traceability technologies to woody products.

Through these interviews, it emerged that many stakeholders are currently implementing traceability at the stand and batch level with the traditional technology previously exposed and/or relying on certification schemas. Yet, this application is limited to high-quality roundwood. In the case of biomass for energy or lower-quality wood assortments such as pulpwood or timber for packaging, traceability at the tree level was considered impractical due to the low unitary value of logs. According to respondents, in such cases, the traceability system could still offer valuable service for management of logistics and stocks, for instance streamlining inventories and bureaucratic processes. When considering the specific classes of respondents, the results can be synthesized as follows:

1) Foresters are generally sceptic regarding the application of real-time and single-item traceability. Many believed it could generate excessive information, administrative burdens, and become cost-prohibitive unless they could incorporate the costs into the product (e.g., by implementing changes to current auction systems to include a variable percentage depending on wood quality classification). However, they also stated that in scenarios involving mechanical harvesting during thinning operations or specific felling methods (thinning operations, shelterwood cutting method, strip shelterwood cutting/felling…), a detailed understanding of the wood present in the forest could prove beneficial.

2) Harvester contractors found interesting to have real time traceability Yet are concerned regarding the additional burden of cost and maintenance on their everyday activity, claiming that they are always the group called to incorporate the costs and risks of any innovation or regulation in the timber value chain. Among the proposed solutions, some respondent suggested that a tax should be applied on wood that cannot demonstrate fulfilment of sustainable production. Similarly, traceability could allow to discriminate locally sourced timber from the raw material originated from far forest resources: in this case the higher CO_2 emissions of transportation should be penalized with taxation.

3) Sawmill industries presented several specific cases where single-item traceability would provide an economic and productive advantage. For instance, the possibility to easily segregate provenance of each log in the yard would allow for precise drying cycles in the kiln drier, reducing losses of sawn product up to 7%, Similarly, the information regarding the position of the log in the original tree and the resulting quality would increase the

optimization of the sawing process and optimize the use of the raw material. The main concerns are focused on the quantity of data to be managed with a traceability system brought to single-item precision. This is particularly relevant in the case of wood composite products like CLT or glulam, where the substantial amount of data generated for a panel or beam might exceed current buyer demands. While simplified information could be presented to the buyer, this data could prove instrumental in enhancing technical decisions within the sawmill, ultimately reducing costs.

4) Public authorities acknowledged interest in automated data flow for administrative efficiency but highlighted that, especially outside northern countries, the forestry industry faced challenges in affording new technologies. Also, in those areas most silviculture operations are still manually done, and digital systems would require careful auditing to prevent fraud. Recognizing the wood's origin could also contribute to increasing public awareness about the importance of silviculture.