DISCUSSION PAPER

HOW ENFIN ENVISIONS A EUROPEAN SYSTEM FOR FOREST MONITORING

The Council Conclusions on the New EU Forest Strategy for 2030 underlines the importance of a sound and transparent data and information base on forests as a basis for policy-making. The Strategy recognizes *"the need to develop a European forest monitoring system based on ground-based data and satellite images".* It points out the demand *"for strategic forest planning in all EU Member States at national, and where applicable, regional level".* The planning needs to be *"based on reliable monitoring and data, transparent governance, and coordinated exchange at the EU level".*

Out of the 27 EU Member States, 23 have an ongoing National Forest Inventory (NFI), additionally 6 countries within the pan-European region are also members of the European National Forest Inventory Network (ENFIN). They all supply forest data and information at national and sub-national levels for up to 100 years. NFIs are fundamental for monitoring the state and development of Europe's forest ecosystems. Specifically, the NFIs possess proven expertise in utilizing the latest remote sensing technologies in combination with their long time series of objectively established monitoring plots.

Thus ENFIN is the key partner, when setting up a forest monitoring system for Europe. Drawing from our experience, we describe the basic principles and requirements of such a monitoring system in this document.

Forest monitoring rests upon two main technical pillars: Remote sensing and field based sample plots. ENFIN envisions a modern and responsive European system for forest monitoring that makes the best use of both worlds through their appropriate combination.

REMOTE SENSING

Remotely sensed data have the big advantage that they are available wall-to-wall and at a higher temporal resolution than field sampling. Aerial photography, laser scanning, and satellite imagery have seen tremendous development and progress over the past decades, improving the quality of information.

Aerial photos contain spectral information at a very high resolution. With overlapping photos, a detailed canopy height model (3D model) at sub-meter level can be calculated through image matching.

Airborne laser scanning (ALS) provides height information, and the resulting 3D model is typically of even higher quality than the one obtained from image matching. It allows the creation of a digital terrain model (DTM) which is needed to obtain vegetation height - the most important parameter to estimate e.g. timber stock. Most EU countries are at least in the process of finishing their first ALS campaign, providing a large-scale wall-to-wall DTM.

EXAMPLES OF POSSIBLE WALL-TO-WALL FINE SCALED PRODUCTS DERIVED FROM AERIAL PHOTOS AND ALS AND THEIR TECHNOLOGY READINESS LEVEL (TRL)[1] ARE THE FOLLOWING:

Forest area mask (TRL7)

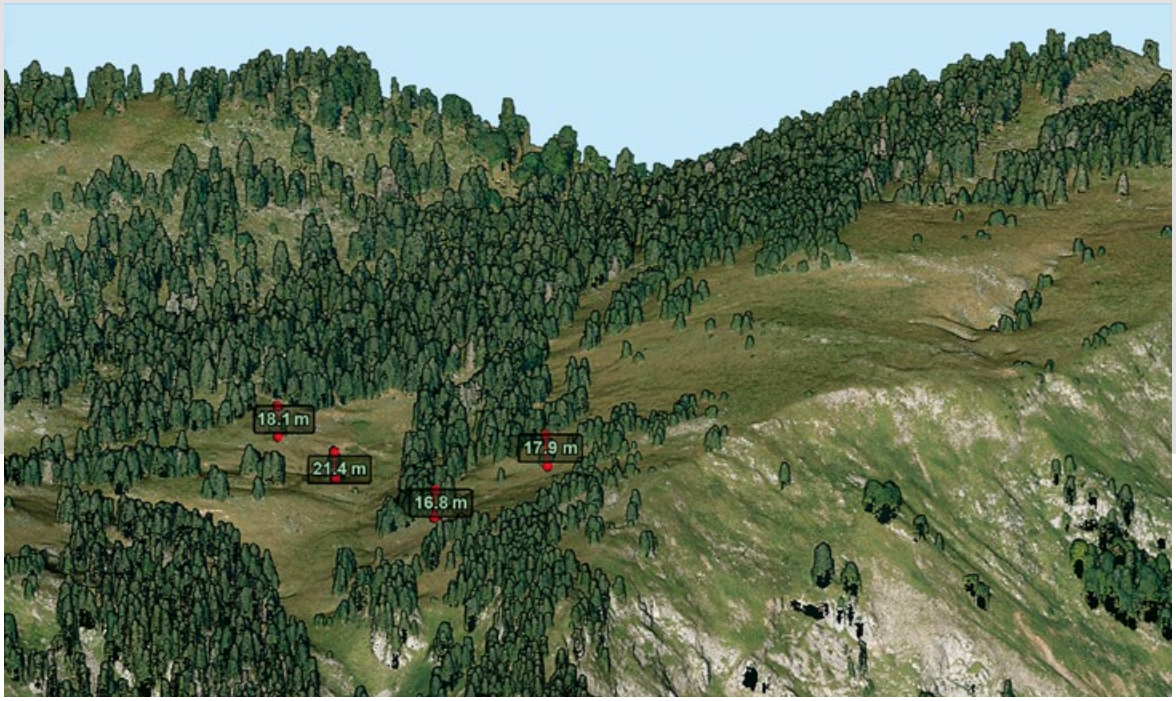
Canopy height map (TRL7)

Large standing dead wood (TRL4)

Forest structure (TRL5)

Maps for the protective effect of the forest (TRL4)

[1] See https://esto.nasa.gov/files/trl_definitions.pdf, TRLs are estimated here for the European scale



Coloured 3D models are more and more emerging in European countries for forest applications. They offer direktly measurements of tree heights and thus form a fundamental basis for fine scale applications starting from the national to the European level.

Satellites, like Sentinel-2 from the Copernicus program, can provide a complete coverage every five days if the cloud conditions permit it. Experiences from the Alpine region show 15 to 40 valid data points on average per year. Images from optical satellites have a much lower spatial resolution than aerial photographs but a much higher temporal and spectral resolution.

Radar satellites, like Sentinel-1, actively scan the Earth's surface and are thus more independent of weather conditions than the optical satellites, adding complementary information about structure and moisture content of objects on the surface.

Satellite-based 3D data is not operationally available wall-to-wall at European level and is also less precise than from aerial images.

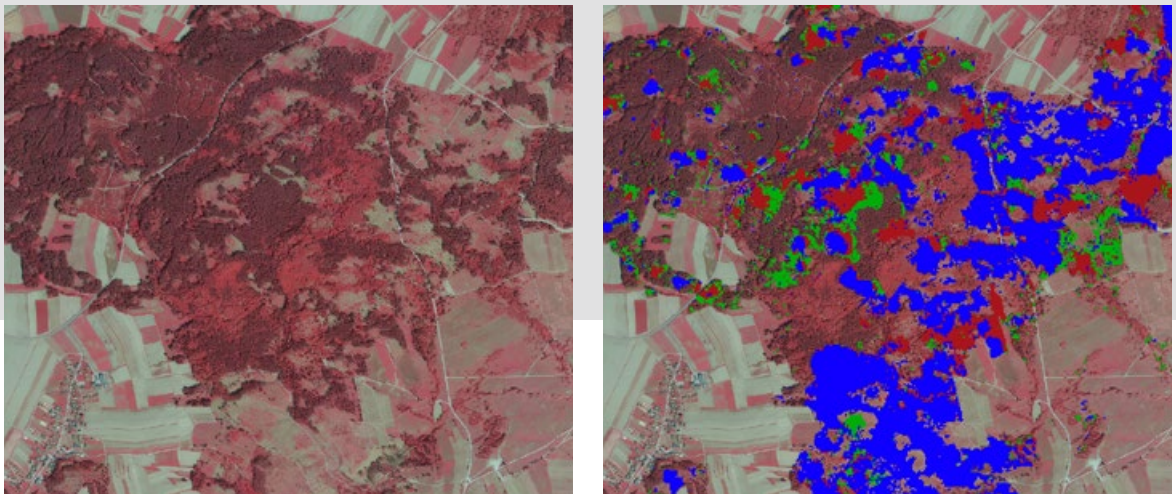
EXAMPLES FOR WALL-TO-WALL PRODUCTS DERIVED FROM SATELLITE DATA AND THEIR TECHNOLOGY READINESS LEVEL:

Maps of changes in forest canopy cover: final harvest, disturbances, etc. (TRL7)

Maps of changes in canopy cover: thinning and selective cutting (TRL4)

Tree species-group maps (TRL7)

A wide range of maps e.g. on land cover already exists on European level, but their quality is often too low for a European forest monitoring. NFIs have a proven expertise in providing such maps in high-quality, but currently they are only operational at national level.



Example for automated disturbance mapping of a heavy bark beetle attack with time series Sentinel-2 data. Left: Infrared Orthophoto (2018). Right: Bark beetle damage area, blue 2018, red 2019 and green 2020.

FIELD BASED SAMPLE PLOTS

Within ENFIN, the national field survey systems consist of a combined number of over half a million field plots with an impressive variety of recorded parameters. Much progress has been achieved in harmonising forest information across Europe since the last 15 years. Examples for the successful harmonisation process, allowing for Europe-wide comparable information, are timber volume, forest biomass increment and forest area available for wood supply. Besides using traditional methods, field data can be recorded using various modern field measurement devices. These measurement devices include e.g. terrestrial laser-scanning (TLS). The implementation would rely on transparent, efficient, and robust methods for field data collection. Merging classical field assessments with TLS provides not only concise information about the current state and change of European forests, but is also an invaluable basis for modelling the future development of forest ecosystems under various scenarios.

POSSIBLE PRODUCTS AND THEIR TECHNOLOGY READINESS LEVEL OF AN INTERNATIONAL FIELD SURVEY SYSTEM ARE:

Statistically sound estimates to cover (inter)national and European reporting for the majority of the required indicators (e.g. Forest Europe, GHG, Biodiversity strategy, FFH reporting) (TRL6-9)

Rigorous uncertainty assessment of all estimates (TRL8)

Harmonisation of the estimation process at the European level (TRL7)

Harmonised forest modelling including management and climate change scenarios (TRL6)

Measurement of lying deadwood requires field based sampling

COMBINING FIELD PLOTS AND REMOTE SENSING

Remote sensing technology is an outstanding addition to any forest survey system, but it needs obligatory statistically correct assessed field data for training, calibration, and validation. NFI field plots are an excellent source of ground-truth data which are usually required in the development of reliable map products. By combining remote sensing data and field data, the best of two worlds can be achieved. The detailed information (like diameter measurements or tree species assessments) obtained in the field is coupled with large-area remote sensing information to create precise statistically-sound estimates of target variables that correlate well with the remote sensing information using statistical models. Also, artificial intelligence can be applied as a type of model to combine these two pillars. Such a Europe-wide undertaking requires an appropriate infrastructure. A mapping and estimation platform for LULUCF, biodiversity or forest management monitoring based on field and remotely sensed data across the EU can be developed, provided that a processing system for big datasets is maintained by a transnational organization that bundles national and European data. A clear European commitment to such a governance structure is required. The integration of both, remote sensing and harmonised field plots, into one system ensures seamless use of data, feedbacks, and mutual learning.

POSSIBLE PRODUCTS OF COMBINED FIELD PLOT DATA WITH REMOTE SENSING AND THEIR TECHNOLOGY READINESS LEVEL ARE:

Timber volume and biomass (carbon) estimates at different NUTS levels (TRL6)

Actual mapping of removed timber volumes due to regular harvest and disturbances (e.g. storms or bark beetle) (TRL5)

Improved timeliness for reporting a set of indicators based on updating field plots with remote sensing and growth models (TRL4)

High-resolution monitoring of forest carbon pools including carbon stock change allowing coherent EU-level LULUCF reporting (TRL4)

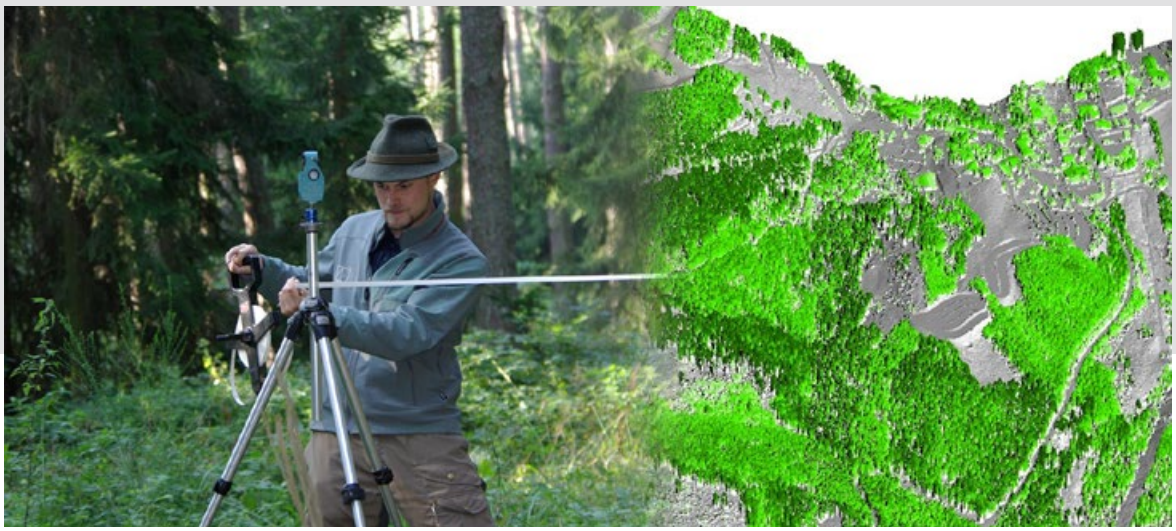
Mapping of high nature value and old growth forests (TRL4)

Mapping and assessing the state of protective forests in Europe (TRL3)

Support for regional planning, tourism, and socio-economic developments (TRL3)

Forest structure maps to derive biodiversity indicators (TRL5)

Implicit and rigorous uncertainty assessment of developed maps through field data (TRL5)



Combining field plot with remotely sensed data offers a wide range of applications.

INNOVATION POTENTIAL

ENFIN is ready to work on innovative methodologies like:

FOREST SIMULATION LINKED TO WALL TO WALL REMOTE SENSING

The state of the art is that forest growth is simulated by using single tree data obtained on forest plots and applying diameter and height growth models. By incorporating remote sensing data, the simulations can be run in areas that do not contain forest plots leading to wall to wall mapped scenario analyses.

OPTIMIZED COMBINATION OF SENTINEL-1 AND SENTINEL-2 DATA

The optimal combination of radar and optical information at a high temporal resolution enables near-real time change detection of abrupt changes more independently of cloud conditions.

INTERSECTORAL ANALYSES OF FOREST AND NON-FOREST LAND USES

Spatially explicit land system change models can be used for simulations of land use changes. Simulating land-system changes in response to various types of demand, land system characteristics, and biophysical and socioeconomic variables will help to understand and correctly interpret the competition and trade-offs within and between land use classes.

INCLUSION OF PROXIMAL SENSING LIKE TLS OR DRONES

With proximal sensing high resolution 3D point clouds can be acquired to open a door into digital twins and virtual reality. It can provide new innovative modelling opportunities and can be linked with wall-to-wall remote sensing technologies with lower resolution.

Combining field plot with remotely sensed data offers a wide range of applications.

INSTITUTIONAL ARRANGEMENTS

ENFIN has the right competencies and skills to reach the goals of a European Forest Monitoring System:
- Reliable monitoring data and information
- Coordinated exchange at the European level
- Transparent governance

Starting from the national level experience, we conclude that establishing such a system calls for institutional arrangements including the following:
- Need for a legal basis
- Continuous EU funding
- Involvement of all NFIs, from field data collection to reporting
- Starting from existing quality control systems and expanding these to European level

The multitude of climatic regions and the diversity in grown structures of forest ownership and management ask for a well-balanced inclusion of national particularities into the governance system. The experience of NFIs enables them to take this into account while at the same time working in a coordinated manner for a European forest monitoring system.

We propose establishing a formal institutionalised ENFIN office coordinating NFI institutions. Together with all relevant stakeholders the ENFIN office would develop a detailed governance structure taking into account the subsidiary principle. It would further strengthen the work on harmonization and the combination with remote sensing technologies and would organise the data flow from national forest information systems to FISE and policy makers.

ENFIN, December 2021