SPACE FOR SUSTAINABLE FORESTRY – USE CASES

This document lists the use cases to be used as part of the "Space for Sustainable Forestry" thematic call for proposals. The use cases presented result from the cooperation between the European Space Agency (ESA) and key stakeholders of the forestry sector. It aims at developing sustainable services leveraging space assets and technology in consort to address key challenges and opportunities to develop operational solutions. When writing the initial proposal (APQ/APQ+ proposal), the applicant will make clear which use case(s) their solution will address, if chosen from those listed here.

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Organizations involved in the descriptions of the use cases:

EUSTAFOR

The European State Forest Association, serves as the collective voice for state forest companies, enterprises, and agencies across Europe, all of which prioritize sustainable forest management (SFM) and the production of wood resources. Formed in 2006, comprising 39 members spread across 27 European countries, EUSTAFOR advocates for policies and practices that promote the sustainable management of forests and the responsible utilization of wood resources. Through collaboration, knowledge-sharing, and engagement with relevant stakeholders, EUSTAFOR aims to ensure the long-term environmental, economic, and social viability of Europe's state-owned forests.

CEPF

The Confederation of European Forest Owners acts as the unified voice for forest owners across Europe, serving as an umbrella association for national forest owner organizations within the EU. Established as a non-profit organization, CEPF is dedicated to promoting the principles of sustainable forest management, private property ownership, and the economic sustainability of the forest sector at the EU level.

With a membership representing over 15 million forest owners, accounting for approximately 60% of the total forest area in Europe, CEPF advocates for policies and initiatives that prioritize the interests and concerns of forest owners. Through its advocacy efforts, CEPF works to ensure that the rights of forest owners are respected, and that forestry practices contribute to both environmental conservation and economic prosperity across the European continent.

Copa-Cogeca

Copa and Cogeca, jointly known as Copa-Cogeca, stand as the unified representation of European farmers and agricultural cooperatives. Founded under the Treaty of Rome in 1957, Copa represents the interests of over 22 million European farmers, while Cogeca advocates for the agri-food, forestry, and fishery cooperatives across the continent. Both organizations operate within the context of EU institutions and engage with relevant stakeholders to influence European decision-making processes.

With a collective mission, Copa-Cogeca strives to ensure the sustainability, innovation, and competitiveness of EU agriculture. By advocating for policies that support sustainable farming practices, technological advancement, and market competitiveness, they aim to safeguard the interests of European farmers and cooperatives. Additionally, Copa-Cogeca plays a vital role in guaranteeing food security for the 500 million people residing in Europe, emphasizing the importance of a resilient agricultural sector in meeting the nutritional needs of the continent.

Österreichische Bundesforste (Öbf)

The Austrian Federal Forests (ÖBf), Austria's leading nature company, manage every tenth square meter of the country, overseeing 850,000 hectares of natural land, including 74 lakes and 15% of its forests. Their mission is to sustainably manage Austria's forests, lakes, and mountains, balancing ecological, economic, and social interests. About half of the areas they manage are subject to nature conservation regulations, with a third of their mountain forests designated as protective forests.

For tenderers who choose to address the use case defined by Öbf a Letter of Interest from a representative of the user community is not needed as Öbf will act as pilot user. In addition to Öbf, the tenderer is also welcome to bring its own user

FSC

FSC is a rigorous and trusted forest certification system. FSC is governed by a global network of members, who represent social, environmental, and economic interests. The decision making-authority is shared with over 1200 members across over 90 countries, including private enterprises, NGOs and other non-profit organisations, academic and research institutions, and individuals, ensuring the integrity and resilience of the FSC system. This democratic and participative system brings these diverse perspectives together to find solutions that safeguard healthy and resilient forests worldwide.

FSC provides tools that help protect forests throughout various stages, ensuring product verification from the forest to the consumer, including manufacturing and retail phases. To ensure responsible management, forest operators can obtain FSC's Management Certification, which is a rigorous standard for sustainable forestry. Additionally, FSC enables Forest Managers (FM) to showcase the positive impact of their responsible forest stewardship through the Ecosystem Service (ES) procedure. This voluntary framework allows forest managers to highlight the true value of the forest beyond the economic value of timber and other products. Forests also provide vital ecosystem services that are harder to quantify, and the ES procedure offers a scientific approach for measuring forest benefits, ensuring that forest managers can effectively protect and communicate the full range of forest contributions to human well-being.

To obtain FSC ES certifications, FM need to create and submit an application for review by a Certifying Body (CB). The audit process is initiated by the CB, after which FSC publishes the application in a digital registry. In addition to yearly audits, subsequent, compliance audits are then also conducted.

For tenderers who choose to address the use case defined by FSC a Letter of Interest from a representative of the user community is not needed as FSC will act as pilot user. In addition to FSC, the tenderer is also welcome to bring its own user.

PEFC

The Programme for the Endorsement of Forest Certification (PEFC) is an umbrella organization that endorses national forest certification systems developed through multi-stakeholder processes and tailored to local priorities and conditions. PEFC is then an alliance of national forest certification systems, NGOs, associations, companies, and individuals founded in 1999. Over 295 million hectares of forest area are managed in compliance with PEFC's internationally accepted Sustainability Benchmarks. PEFC aims to promoting sustainable forest management through independent third-party certification to demonstrate the responsible practices of forest owners, while empowering consumers and companies to buy sustainably.

For tenderers who choose to address the use cases defined by PEFC, PEFC will share the proposed solutions with their stakeholder's community, providing visibility and potential opportunities. However, companies will still be required to secure a user through a Letter of Intent (LoI) to move forward.

The use cases

Use case: Natural Disasters Response Support (EUSTAFOR, CEPF, Copa-Cogeca, ÖBf)

Problem statement

Forests are very vulnerable to extreme weather events (e.g. droughts, storm, flood) which often lead to forest degradation and deforestation. Amongst natural disasters, windstorms are considered the main dangerous for European forests. They affect a multiplicity of forest-related dimensions, such as forest ecology, forest operations, geomorphology, economy, and socio-cultural aspects. Between 1950 and 2000, windstorms accounted for 53% of the total damage caused by abiotic agents to European forests, totalling more than 900 million m^3 of windthrown timber with an average yearly damage of 18.7 million m^3 [1].

While wind remains the most significant abiotic disturbance affecting forests, snow has a substantial impact on forests. For instance, the winter of 2020–2021, resulted in an estimated economic loss of EUR 3 million in Norway due to extensive forest damage. Across the European Union, snow damage has annually accounted for 1 to 6 million m^3 of timber loss, representing up to 3% of total forest damage over the past century. In Finland, snow damage has been responsible for 7% of insurance payouts to forest owners, averaging EUR 0.5 million annually over the last 30 years[2]. Similarly, ice storms and snow can inflict large damages to trees[3], as seen in 2014 when an extreme ice storm affected 500 thousand hectares of Slovenian and Croatian forests, leading to the loss of 1.2 million m^3 of timber[4].

When the damage to forests is severe, the negative impacts can last long because of the lengthy process generally involved in forest recovery. Moreover, forests that have been destroyed or seriously damaged by disasters may suffer secondary impacts, such as pest outbreaks, wildfire and erosion.

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[1] Romagnoli, F., Cadei, A., Costa, M., Marangon, D., Pellegrini, G., Nardi, D., Masiero, M., Secco, L., Grigolato, S. Lingua, E., Picco, L., Pirotti, F., Battisti, A., Locatelli, T., Blennow, K., Gardiner, B., Cavalli, R. (2023) Windstorm impacts on European forest-related systems: An interdisciplinary perspective, Forest Ecology and Management, Vol. 541 https://www.sciencedirect.com/science/article/pii/S0378112723002827

[2] Zubkov, P., Gardiner, B., Nygaard, B. E., Guttu, S., Solberg, S., & Eid, T. (2023). Predicting snow damage in conifer forests using a mechanistic snow damage model and high-resolution snow accumulation data. Scandinavian Journal of Forest Research, 39(1), 59-75.

[3] Guo, S. and Xue, L. (2012). Effects of ice-snow damage on forests. Acta Ecol Sin (in Chinese)

[4] Nunes-Romeiro, J. M., Eid, T., Antón-Fernández, C., Kangas, A., Trømborg, E. (2022). Natural disturbances risks in European Boreal and Temperate forests and their links to climate change – A review of modelling approaches. Forest Ecology and Management, Vol. 509, 120071.

As a result of a disaster, huge amount of wood- often not of the best quality as the trees were not supposed to be cut down yet - are suddenly available and this can disrupt the supply of forest products and environmental services. Harvesting companies are impacted as they have to gather and manage huge stack of wood which was not planned and also the other actors in the supply chain (e.g. supplier of timber, woodfuel, non-wood forest products) are negatively concerned by the unforeseen overproduction and hence by the price decreases. Often neither harvesting machines nor personnel is sufficiently available to handle the amount of damaged wood mass. It happened recently in Italy that several companies had to travel from Austria and Czech Republic to work in the impacted area and therefore creating shortages in harvesting capability in the not affected areas generating a negative snowball effect.

During the extreme events, forest owners are unaware of the extent of the damage. It is not safe to access the site and flights are not permitted because of the bad weather therefore space-based information is the only mean to get an assessment of the size of the impacted area and the type of the damage. Each information is essential to plan the intervention: to know where and how many people need to be mobilised for the recovery. Often roads are blocked by fallen trees or sometimes even by landslides so the area is inaccessible till trees are removed. A quick and reliable post-disaster assessment is also needed by the government that often-particularly in the Central and Eastern European Countries-are also the owners of the forestry and must accommodate for the financial resources required in the post-emergency phase. Currently, some services already exist on the market, but they lack accuracy with a correct detection of max 60% of the damage in the best option.There is also a need for a timely assessment of the extent of the damage. The clearing of a disaster event could take 4 to 8 weeks depending on the terrain and accessibility; the big advantage for a forest company would be to know if and how many acres of forest are affected as soon as possible after the event (ideally after 5 days at latest).

Damage information collected after several weeks is obsolete, as other companies will already have collected the wood resources.

For tenderers who choose to address the use case defined by ÖBf a Letter of Interest from a representative of the user community is not needed as ÖBf will act as pilot user. In addition to ÖBf, the tenderer is also welcome to bring its own user.

Role of Space

Earth observation (EO) can be used to estimate the size of the area impacted by the extreme event and to estimate the species of trees. A combination between optical and radar images can ensure a complete coverage independently of the weather conditions.

Earth Observation data is the perfect tool to measure to which extent the natural hazard is occurring and to monitor this data throughout the years can lead to a better understanding of these events, so then they can be eventually predicted in the future.

Satellite Navigation (SatNav) can be employed to integrate and geo-reference local environmental and weather data measured by in situ sensors.

Integrated in situ and EO data unlock solutions which are important for the marketing intelligence to forecast the availability of wood-and other forest related products-in the market and therefore the pricing fluctuations.

Navigation data enable high precision positioning, navigation and tracking people, vehicles.

Satellite Communication (SatCom) can be used to: provide ubiquitous connectivity when the terrestrial network is not available. (i.e. disaster situations or often in mountainous area).

Use case: Insect Pest and Disease Monitoring (EUSTAFOR, CEPF, Copa-Cogeca, ÖBf)

Problem statement

It is well known that insect pests and disease have considerable impacts on forests. They can adversely affect tree growth and the yield of wood as well as of non-wood products. Damage caused by forest pests can significantly impact wildlife habitat reducing local biodiversity and species richness. Forest insect pests and diseases may also result in the limitation of plantation programmes, the abandonment of a given tree species and the necessity to clearcut large areas dominated by infested trees[5].

Another factor to consider is the impact on the human health as the risk of zoonotic diseases, which spread from animals to humans, is linked with deforestation. Those diseases are usually hold back and filtered by the healthy forests. Therefore, when the "trees barrier" disappear or is reduced, humans are more likely to be contaminated by these infectious diseases[6]. An example is that the three percent rise in malaria cases in the Amazon between 2003 and 2015 was linked with the 10% deforestation. As deforestation rates accelerate, more epidemics are likely to be expected.

Outbreaks of pests and pathogens not only cause significant loss in biodiversity, but they also cause significant economic and social losses. According to research, pests could devastate the flow of woodland ecosystem services, which contribute £3.3 billion to the UK economy annually[7]. Forest managers are therefore interested in minimising economic losses due to disease in terms of the timber benefit.

Globally, one of the most infesting insects affecting forests is the bark beetle mainly hosted on the Norway Spruce. This tree species represents 25 percent of European forests coverage[8]. The bark beetle harm the trees by laying their eggs under the bark of living trees. Once the larvae are born, they feed from the inner woody layers the which weakens the tree and most of the time it kills them [9]. Outbreaks of the bark beetle are often associated to windstorms as trees are weakened after a storm, so the bark beetle has a better chance to breed. Bark beetle disturbances have doubled their share of total forest damage over the past 20 years[10].

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[5] Allard, G.B, Fortuna, S., See, L. S., Novotny, J., Baldini, A., Courtinho, T. Global information on outbreaks and impacts of major forest insects, pest and diseases. XII World Forestry Congress, 2003. https://openknowledge.fao.org/server/api/core/bitstreams/a2cc6101-c03a-4205-afd4-5a911fd268d3/content

[6] Deforestation is leading to more infectious diseases in humans (nationalgeographic.com)

[7] McTaggart, E., Megiddo, I., Kleczkowski, A. (2023). The effect of pests and pathogens on forest harvesting regimes: A bioeconomic model, Ecological Economics, Vol. 209 https://www.sciencedirect.com/science/article/pii/S0921800923000630#b28

[8] Zeidler, A.; Borůvka, V.; Brabec, P.; Tomczak, K.; Bedřich, J.; Vacek, Z.; Cukor, J.; Vacek, S. The Possibility of Using Non-Native Spruces for Norway Spruce Wood Replacement—A Case Study from the Czech Republic. *Forests* **2024**, *15*, 255. https://doi.org/10.3390/f15020255

[9] Great spruce bark beetle (Dendroctonus micans) - Forest Research

[10] Březina, D., Michal, J., and Hlaváčková, P. (2024). The Impact of Natural Disturbances on the Central European Timber Market—An Analytical Study. *Forests* 15, no. 4: 592. https://doi.org/10.3390/f15040592

In 2019, the bark beetle affected nearly 23 million m^3 of the harvested timber in Czech Republic[11]. In 2020, Germany lost 43.3 million m^3 of timber due to this species[12]. In early stages of bark beetle infection, forest owners can cut the affected trees to save the wood resources. Once cut, the bark beetle cannot further breed. Unfortunately, it is hard to make a distinction between the pest disease and trees' drought. Later, in the red-stage of the disease, when it is detectable, it is too late to recover the wood resources.

ÖBf is actively seeking for solutions which would detect bark beetle infections at early stages. These solutions would enable to reduce timber losses by enabling correcting measures being taken on time. ÖBf is also looking for solutions which could detect forest stands which need to be thinned.

For tenderers who choose to address the use case defined by ÖBf a Letter of Interest from a representative of the user community is not needed as ÖBf will act as pilot user. In addition to ÖBf, the tenderer is also welcome to bring its own user.

Best practises of sustainable forest management shall cater also for measures aimed at protecting forest from insect pests and diseases to minimize the risks and associated impacts of such unwanted phenomenon.

Role of Space

Earth observation (EO) Thinning-in the sense of reducing tree density and of removing diseased trees- is considered as one of the primary precautionary strategies to reduce disease impact and to increase the value extracted by the timber[13]. To perform thinning, forest managers need to know whether and when to thin and they need also to balance between harvesting-before a disease can damage the wood- and preserve forest density.

EO satellite can provide the data required for the forest inventory and to estimate the vegetation density. EO data are also helpful in the identification of the tree species which is an information required by the forest managers for species rotation which is another method of disease control.

New satellite multispectral data gives the opportunity to differentiate between stages of bark beetle infection.

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[11] T. Hlásny, S. Zimová, K. Merganičová, P. Štěpánek, R. Modlinger, M. Turčáni, Devastating outbreak of bark beetles in the Czech Republic: Drivers, impacts, and management implications, Forest Ecology and Management, Volume 490, 2021,

[12] Nunes Romeiro, J. M., Eid, T., Antón-Fernández, C., Kangas, A., Trømborg, E. Natural disturbances risks in European Boreal and Temperate forests and their links to climate change – A review of modelling approaches, Forest Ecology and Management, Vol. 509, 2022.

[13] McTaggart, E., Megiddo, I., Kleczkowski, A. The effect of pests and pathogens on forest harvesting regimes: A bioeconomic model, Ecological Economics, Vol. 209, 2023.

Satellite Navigation (SatNav) can be employed to integrate, and geo-reference local environmental and weather data measured by in situ sensors.

Local sensors are needed to improve the measurement methods, thus reducing the need and frequency of field visits and to have consistent and more frequent in-situ measurements to estimate and assess forest growth.

Satellite Communication (SatCom): given the remote depopulated nature of forests it is typical that forests do not always have wireless terrestrial coverage. Satellite communication systems will provide access to the data regardless of the location of the forest plots. The SatCom solution will overcome this problem and provide the necessary communication to the measurement in-situ sensors.

Use case: Carbon Storage Estimation (EUSTAFOR, CEPF, Copa-Cogeca, PEFC and FSC)

Problem statement

Forests play a crucial role in mitigating climate change by absorbing and storing carbon from the atmosphere through photosynthesis, a process integral to the global carbon cycle. Covering 30% of the world's terrestrial land area and holding 81% of the earth's terrestrial carbon biomass[14], forests act as a two-way path: they absorb CO_2 when standing or regrowing and release it when cleared or degraded. However, data shows that forests absorb twice the carbon they emit annually. On average, forests emit 8.1 billion metric tonnes of carbon dioxide into the atmosphere each year due to deforestation and other disturbances and absorb 16 billion metric tonnes of CO_2 per year[15].

Both forest owners and managers-which are trying to diversify their forest-based revenue streams- and financial institution operating in the carbon trading ask for solutions which are aimed at improving both vegetation carbon storage and soil carbon storage estimation. Estimate carbon in a forest is not a trivial feature especially for forest owners who need to rely on third party developers. Traditional carbon monitoring methods, which rely on tree characteristics like height, are often labour-intensive and may not provide the accuracy needed for effective carbon management and trading. Therefore, it is essential to improve the reliability and robustness of data at the single tree and species level.

Building on the use of space technology for forest inventory, there is significant potential to enhance the monitoring of carbon sequestered in forests. Forest inventory data provides essential insights into wood production and carbon sequestration, which are vital for sustainable forest management[16]. Accurate monitoring of these factors is crucial, as the sources and sinks of carbon in forests depend heavily on management practices and spatial patterns of forest productivity.

Role of Space

Earth observation (EO) has the capability to support the quantification of Above-ground Biomass (AGB), which is a key indicator of forest ecosystem carbon sequestration capacity and reflects the complicated relationship between the nutrient cycle and

[14] Fetene, T. A. Quantifying Carbon Sequestration of Forest Ecosystem Using GIS and Remote Sensing; the Case of Yeraba State Forest East Gojjam Zone Amhara Regional State. *Preprints* 2024, 2024070571. https://doi.org/10.20944/preprints202407.0571.v1

[15] https://www.wri.org/insights/forests-absorb-twice-much-carbon-they-emit-each-year

[16] Birdsey, R., Plantinga, A.J., Heath, L.H. (1993). Past and prospective carbon storage in United States forests, Forest Ecology and Management, Vol. 58, Issues 1–2.

energy flow[17]. Forest AGB can be evaluated using parameters such as optical sensor-derived surface reflectance, vegetation indices (Vis), Leaf Area Index (LAI), coverage, and tree and canopy height. By combining optical imagery with field measurements, AGB can be quantified through reflectance values and indices like the normalised difference vegetation index (NDVI) or difference vegetation index (DVI). LiDAR data further enhances precision by providing tree height measurements, canopy area, and stand density data, which, when integrated with field data and other metrics, refine biomass estimates and improve AGB estimation in dense forests. Additionally, radar data through interferometry and polarisation, for example, offers measurements of tree height and forest structure, which is frequently used for biomass estimation at forest stand structure level.

Satellite Navigation (SatNav) can ensure accurate positioning and mapping of forest areas. SatNav ensures precise placement of field plots, enabling the effective overlay of field data with EO measurements for biomass estimation. By facilitating the tracking of individual trees, SatNav supports the development of allometric equations that link indices from remote sensing, such as crown projection area, to individual tree-based carbon estimates. This integration of SatNav enhances the accuracy of carbon stock calculations and forest stand assessments by aligning spatial data from both remote sensing and field measurements.

Satellite Communication (SatCom) can allow for the efficient transfer of data collected through in-situ measurements to databases for its analysis especially in remote or inaccessible forest areas where terrestrial networks are unavailable.

For tenderers who choose to address the use case defined by FSC a Letter of Interest from a representative of the user community is not needed as FSC will act as pilot user. In addition to FSC, the tenderer is also welcome to bring its own user.

[17] Tian, L.; Wu, X.; Tao, Y.; Li, M.; Qian, C.; Liao, L.; Fu, W. (2023). Review of Remote Sensing-Based Methods for Forest Aboveground Biomass Estimation: Progress, Challenges, and Prospects. *Forests 14*, 1086. https://doi.org/10.3390/f14061086

Use case: Improvement of Ecosystem Service Verification (FSC).

Problem statement

As environmental concerns become increasingly urgent, the demand for transparent and verifiable sustainable forestry practices will only grow. As markets and regulations increasingly prioritise sustainability, the ability to demonstrate verified and trustworthy ecosystem service claims will become indispensable.

FSC is in the process of developing an ES registry, which requires Forest Managers (FM) to submit indicator values for their ES certification. These indicators, which will allow them to measure and verify responsible forestry practices, include: biodiversity conservation, carbon sequestration and storage, watershed services, soil conservation, recreational services, cultural services (under development), and air quality. By comparing these indicators against established baseline values, FMs can indisputably demonstrate their positive impact on the ecosystem. However, estimating these indicators, such as air quality and carbon levels, can potentially be extremely challenging. Additionally, identifying the baseline input data and the proper methodology to assess the impact within forest ecosystems is necessary for the different indicators.

Currently, FSC is placing high priority on two of these ecosystem services (see Annex Table 'Ecosystem Services Indicators' for further disclosure):

- Biodiversity conservation.
- Carbon sequestration and storage.

This use case focuses on the estimation of these two high-priority indicators and on the creation of a baseline for evaluating the status of ecosystem services. This baseline will provide the necessary data to determine the current status of the areas under evaluation.

FSC is actively seeking for solutions which will support the process of Ecosystem Service verification for certification. It is also envisaged that FSC will facilitate the interactions between solutions which have proven to ease the ES certification process for the FM.

The reader is referred to the Annex Ecosystem Services Indicators table for information about the different indicators that FMs need to estimate. Examples of outcome indicators include area of natural forest cover resulting from afforestation/reforestation, forest density, survival rate of planted native species, forest ecosystem structure, habitat connectivity, pest control, estimated carbon stocks across the entire management unit or carbon emissions related to forestry operations. Note that FMs can choose which impact(s) to demonstrate based on the type of ES certification they are seeking.

Role of Space

Satellite data plays a crucial role in the ES certification process, allowing for precise, synoptic Monitoring, Reporting, and Verification (MRV)of ecosystem impacts. This application EO data is instrumental to ES certification as a transparent, high-integrity market instrument for sustainable forestry.

Earth observation (EO) can be used to estimate the indicators, monitor the status and provide imagery as mapping related to natural forest cover, intact forest landscapes, ecologically sufficient conservation area networks, carbon stocks through afforestation, reforestation and restoration, carbon stocks through forest conservation or protection, water quality, capacity of watersheds to purify and regulate water flow, soil condition, air quality, cultural values and services as manifest in nature, population of species of interest for nature-based tourism and rare, endemic, threatened or endangered habitats or ecosystems, and more.

In addition to EO data, it is important to highlight terrestrial-based technologies and in-situ technologies, which are becoming increasingly valuable including:

- **Light Detection and Ranging (LiDAR)**: provides precise three-dimensional measurements of vegetation structure and terrain, enabling the derivation of digital elevation models and accurate forest inventory data. This information could be used and combined with multispectral data to estimate natural forest structure, populations of species of interest for nature-based tourism, soil stability and protection against erosion, species diversity and functional biodiversity.
- **Internet of Things (IoT) technology**: by deploying sensors and IoT devices, real-time data on tree health, soil moisture, and environmental conditions can be obtained, supporting the estimation of the indicators using EO data. These technologies offer invaluable insights to enhance natural forest cover, carbon stocks, water quality and capacity of watersheds purify and regulate water flow as they allow to detect early signs of disease, pest infestation, or environmental stress. Additionally, IoT facilitates continuous surveillance of wildlife and vegetation, supporting enhancement of an ecologically sufficient conservation area network, and more.
- **Bioacustics**: by using this technology, biodiversity can be monitored and analysed, particularly detecting, and identifying species presence and behavior. Combining this technology with EO data will help understanding species distribution and ecosystem health.
- **Environmental DNA (eDNA)**: this can provide critical information on biodiversity and species abundance, and combined with EO data, it enhances the ability to monitor and protect biodiversity more effectively supporting more effective conservation and management strategies.

Satellite Navigation (SatNav) can be employed to integrate local environmental and weather data. Drones provide high-resolution and real-time imagery to evaluate the natural forest cover, pest infestation, track wildlife, etc.

Forests often cover areas that lack terrestrial communication. **Satellite communication (SatCom)** can complement existing networks. This can for example be useful for connecting sensors and IoT devices. SatCom enables to send the collected data to the interested parties regardless of their geographical location.

For tenderers who choose to address the use case defined by FSC a Letter of Interest from a representative of the user community is not needed as FSC will act as pilot user. In addition to FSC, the tenderer is also welcome to bring its own user.

Use case: Improved Forest Inventory (PEFC, FSC)

Problem statement

In recent decades, the demand for comprehensive forestry information has grown significantly not only to support and plan timber supply, but due to increased awareness of forest health, biodiversity, and the critical role forests play in mitigating global warming. This heightened awareness, particularly evident since the early 1980s, has coincided with rising pressure in some regions to boost timber consumption[18]. Consequently, accurate and reliable forest data is crucial for planning sustainable forest management operations.

Forest inventories provide the primary source of information for forest management by surveying the location, composition, and distribution of forest resources within a specified area. These inventories are vital for resource evaluation and supporting management decisions at various levels and also provide reference information to various monitoring activities related to policy instruments[19]. The process of producing forest inventory data involves multiple stages, ultimately leading to the creation of a digital spatial database[20].

However, conducting regular site and sample-based forest inventories has become increasingly costly due to the significant time and human resources required. Moreover, the precision of traditional methods can vary greatly, which delivers and often less comparable dataset in an international context. This variability and the time-consuming process to collect and access the data hinders effective decision-making, as stakeholders require highly accurate and detailed information in a short period of time. Proposals comparing space technology-based forest inventory data with conventional methods could highlight the benefits of using space technology for more precise and reliable results in more time and cost-efficient manner.

Accurate and up-to-date forest inventory data is essential for understanding species composition, estimating standing stock, and tracking annual removals. It is particularly important for industry stakeholders sourcing timber, as well as for forest managers and owners committed to sustainable forest management.

Role of Space

Earth observation (EO) can be used to identify and map different tree species, forest type, density, height and forest condition across large forest areas, using both optical and radar images. EO can be used to estimate the volume of standing stock by analysing canopy structure and density. Besides, EO can enable monitoring of logging activities and natural losses, helping to track annual removals and changes in forest cover over time.

Satellite Navigation (SatNav) can be used to geo-reference data collected by in-situ sensors, enhancing the accuracy of field measurements and mapping efforts. SatNav can be used to facilitate accurate field plot coordinates and navigation of field teams and machinery,

[18] Tomppo, E. (2004). Resource assessment: Forest resources. Finnish Forest Research Institute.
[19] https://environment.ec.europa.eu/topics/forests/deforestation/regulation-deforestation-free-products_en
[20] Wulder, M.A. (2004). Resource assessment: GIS and Remote Sensing. Canadian Forest Service.

ensuring efficient and precise data collection during forest inventories. Accurate field plot coordinates provided by SatNav are crucial for seamlessly integrating field-measured inventory attributes with high-resolution remotely sensed data, enabling a direct and meaningful comparison.

Satellite Communication (SatCom) can enable continuous data transmissions and communication, especially in remote or inaccessible forest areas where terrestrial networks are unavailable. SatCom can support real-time monitoring and reporting during forest inventories.

Use case: Agroforestry (PEFC, FSC)

Problem statement

The global demand for timber products is expected to quadruple by 2050 according to the World Bank[21], driven by population growth and industrial needs. However, expansion of industrial plantations is constrained by competition from alternative land uses, as agricultural lands occupied 4.8 billion ha in 2021, or 38% of the global land surface[22],[23]. Besides, timber from natural forests is increasingly less available because of conservation, environmental and social concerns.

In this context, agroforestry systems, where trees are integrated into agricultural landscapes, offer a promising solution. Trees on farms have long been recognised for their multiple benefits, including enhancing soil fertility, assisting in soil and water conservation, and providing fodder, fuelwood, and construction materials for rural households. They also contribute to biodiversity and landscape enhancement[24].

Understanding the timber resources available in agricultural areas managed by non-forestry stakeholders is crucial. Gathering detailed information on the types and quantities of trees, growth rates, and potential yields is essential. Proposals to map trees outside traditional forest resources can provide valuable insights and information for targeted capacity building, enabling non-forestry stakeholders to access timber-based supply chains and improve their management of trees. This approach will support to bridge the gap between the growing demand for timber and the limitations of traditional forest expansion, supporting sustainable timber production and enhancing farm livelihoods.

Role of Space

Earth observation (EO) can enable the estimation of the regions and areas under agroforestry, discriminating between agroforestry systems and forests, using for example land cover/land use classifications (LULC), Leaf Area Index (LAI) or Canopy Closure (CC).

[21] World Bank. 2016. "World Bank Group Forest Action Plan FY16–20." World Bank, Washington DC. License: Creative Commons Attribution CC BY 3.0 IGO

[22] https://www.fao.org/sustainability/news/detail/en/c/1274219/

[23] FAO. 2023. Land use statistics and indicators 2000–2021. Global, regional and country trends. FAOSTAT Analytical Briefs Series No. 71. Rome. https://doi.org/10.4060/cc6907en

[24] https://www.fao.org/4/y4744E/y4744e14.htm

Besides, remote sensing techniques using optical and radar data can be used to estimate the area covered by trees within the agroforestry land, quantifying for example the per-pixel basal area proportions of tree species, allowing of the separation of majority of species, species composition and species proportions. Lidar can enable the identification of individual trees, using different methodologies such as canopy height models-based or cloud-based approaches.

Satellite Navigation (SatNav) can ensure accurate geolocation of timber resources, facilitating efficient mapping and management by integrating spatial data with on-ground information. SatNav signal can also be used to provide coarse to high accuracy positioning information to autonomous vehicles (i.e. robots).

Satellite Communication (SatCom) can ensure coverage and provide the necessary communication to the measurement in-situ sensors.

Use case: Deforestation (PEFC, FSC)

Problem statement

Deforestation remains a critical global issue, with an estimated 10 million has of forest lost each year[25]. While addressing this challenge is crucial, a deeper understanding of the technology used to monitor deforestation is essential. Specifically, there is a need to clarify how the technology can distinguish between areas where regeneration is already established after a final cut and those that have been deforested.

This understanding is particularly relevant for key stakeholder groups: industry players sourcing timber within the EU and from outside the EU, with new regulations touching this topic[26], and forest managers or owners located outside the EU. Enhancing technological capabilities to differentiate between these types of deforestation will improve transparency, support more effective forest management, and ensure more responsible sourcing practices.

Role of Space

Earth observation (EO) can provide information about the temporal evolution of relevant spectral indices, such as NDVI or LAI, to analyse abrupt decrease of activity. This information combined with different methodologies, can provide information on the probability of these changes coming from clear-cut activities, for example. Besides, LULC maps could enable to detect changes of forest structure over time, facilitating monitoring of deforestation activities. Additionally, radar data can be used to identify decreases in surface height by deriving Digital Surface Models (DSMs).

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[25] https://www.fao.org/state-of-forests/en/#:~:text=Between%202015%20and%202020%2C%20the,80%20million%20hectares%20since%201990.

[26] https://environment.ec.europa.eu/topics/forests/deforestation/regulation-deforestation-free-products_en

Satellite Navigation (SatNav) can ensure precise geolocation of affected areas while also integrating and geo-referencing local environmental and weather data measured by in situ sensors.

Satellite Communication (SatCom) can be used to provide alarm systems when illegal activities are being detected and the terrestrial network is not available.

Use case: Forest degradation (PEFC, FSC)

Problem statement

Forest degradation is a pressing issue. This degradation, driven by human activities, severe climatic events, fire pests, diseases, and other environmental disturbances, can significantly reduce the provision of forest goods and services, biodiversity values, productivity, and overall forest health[27].

The European Union Deforestation Regulation (EUDR) emphasizes the need to address forest degradation, but a key challenge is the technology's ability to accurately differentiate between tree species. This occurs because of challenges in accurately detecting and delineating individual trees under different forest conditions, leading to an underestimation of the number of stems and a bias toward larger trees[28]. These issues make it difficult to identify tree species effectively in industrial operations, even though it is crucial for applying the EUDR's definition of forest degradation.

Accurate identification of tree species is essential for industry stakeholders sourcing timber (based in the EU) and forest managers/owners (located outside the EU) to comply with regulations and manage forests sustainably. Enhanced technological capabilities for identifying and classifying tree species will improve regulatory compliance, support sustainable forest management, and mitigate the adverse effects of forest degradation.

Role of Space

Earth observation (EO) can be used to identify and classify the unique reflectance signature of different tree species. High-spatial resolution images, time-series images and LIDAR data can be used for forest stands classification.

Satellite Navigation (SatNav) can ensure accurate positioning and mapping of forest areas, integrating spatial data with species-specific information to enhance the precision of trees identification and degradation assessments.

[27] https://openknowledge.fao.org/server/api/core/bitstreams/8f599970-661d-45f5-a598-2ea46ca1605f/content/src/html/deforestation-land-degradation.html

[28] L. Wallace, A. Lucieer and C. S. Watson, "Evaluating Tree Detection and Segmentation Routines on Very High Resolution UAV LiDAR Data," in IEEE Transactions on Geoscience and Remote Sensing, vol. 52, no. 12, pp. 7619-7628, Dec. 2014

Satellite Communication (SatCom) can guarantee coverage and facilitate the necessary communication with the in-situ measurement sensors.

For tenderers who choose to address the use case defined by FSC a Letter of Interest from a representative of the user community is not needed as FSC will act as pilot user. In addition to FSC, the tenderer is also welcome to bring its own user.

Overview of the organizations and related use cases:

	Eustafor	CEPF	Copa-Cogeca	FSC*	PEFC	Obf*
Use case						
Natural Disaster Response	x	x	x			x
Pest Disease & Monitoring	x	x	x			x
Forestry Inventory				x	x	
Agro-forestry				x	x	
Deforestation				x	x	
Carbon Storage Estimation	x	x	x	x	x	
Forest Degradation				x	x	
Ecosystem Service Verification				x		

* **For tenderers addressing use cases proposed by FSC or Obf the letter of intent from a user representative is not needed.**

Annex Ecosystem Services Indicators Table

ES1: Biodiversity conservation		
ES1.1: Enhancement of natural forest cover		
The organisation shall select at least one outcome indicator to measure the following:	1. Extent of natural forest cover from reforestation/restoration activities	• Area of natural forest cover resulting from afforestation/ reforestation • Restored forest area as a proportion of total forest area
	AND	
	2. Quality of natural forest cover from reforestation/restoration activities	• Forest density • Survival rate of planted native species • Variety of plant species composition • Diversity of forest structure
ES1: Biodiversity conservation		
ES1.2: Maintenance of Intact Forest Landscapes		
The organisation shall select at least one outcome indicator to measure the following:	1. Extent of intact forest landscapes in the management unit	• Area of Intact Forest Landscapes • Area of Intact Forest Landscape cores • Area of protected Intact Forest Landscapes
ES1: Biodiversity conservation		
ES1.3: Maintenance of an ecologically sufficient conservation area network		
The organisation shall select at least one outcome indicator to measure the following:	1. Connectivity of the conservation areas network	• Connectivity of the conservation areas network • Connectivity to conservation areas outside the management unit • Connectivity to natural habitats outside the conservation areas network • Size of ecological corridor
	AND	
	2. Habitat quality of the conservation areas network	• Area of the conservation area network within and outside the management unit (including representative sample areas, conservation zones, protection areas, connectivity areas, and high conservation value areas) • Area with high conservation value (HCV) • Proportion of HCV area within the conservation area network • Area of habitats of conservation importance

		• Area of suitable habitats for species with conservation value • Area of large landscape level ecosystems and mosaics (HCV2)
ES1: Biodiversity conservation		
ES1.4: Enhancement of an ecologically sufficient conservation area network		
The same as per Impact ES1.3		
ES1: Biodiversity conservation		
ES1.5: Maintenance of natural forest structure		
The organisation shall select at least one outcome indicator to measure the following:	1. The forest structure	• Forest age class • Forest ecosystem structure • Forest structural condition index • Forest vertical and/or horizontal structure • Amount of standing and fallen deadwood and/or other important natural microhabitats
ES1: Biodiversity conservation		
ES1.6: Enhancement of natural forest structure		
The same as per Impact ES1.5		
ES1: Biodiversity conservation		
ES1.7: Maintenance of species diversity		
The organisation shall select at least one outcome indicator to measure the following:	1. Native species diversity	• Indices of species assemblage or composition (e.g. birds, mammals, trees, fish, beetles) • Proportion of species classified as at risk
	OR	
	2. Abundance or viability of focal, endemic or rare, threatened and/or endangered species	• Abundance of selected species • Availability of selected species for sustainable traditional use (e.g. medicinal plants)
	AND	
	3. Habitat availability within the management unit for focal, endemic, or rare, threatened and/or endangered species	• Area of available habitat • Suitability of habitat • Habitat connectivity • Area protected from illegal hunting
ES1: Biodiversity conservation		
ES1.8: Enhancement of species diversity		
The same as per Impact ES1.7		

ES1: Biodiversity conservation		
ES1.9: Maintenance of functional biodiversity		
The organisation shall select at least one outcome indicator to measure the following:	1. Ecological function	• Pollination rates • Seed dispersal • Pest control • Gross or net primary production • Population dynamics
	OR	
	2. Functional biodiversity	• Specifies richness of native pollinators • Abundance of natural enemies (e.g. bats) that limit pests • Variety of functional species groups • Diversity of morphological species traits • Diversity of soil microbiome
	AND	
	3. Habitat availability within the management unit for functional biodiversity	• Evidence of roosts and shelters in use by functional species • Area of available habitat for functional biodiversity species • Suitability of habitat for functional biodiversity • Availability of standing and fallen deadwood and/or other important natural microhabitats
ES1: Biodiversity conservation		
ES1.10: Enhancement of functional biodiversity		
The same as per Impact ES1.9		
ES1: Biodiversity conservation		
ES1.11: Maintenance of rare, endemic, threatened or endangered habitats or ecosystems		
The organisation shall select at least one outcome indicator to measure the following:	1. Extent of rare, endemic, threatened or endangered habitats or ecosystems	• Area of endemic habitats or ecosystems • Area of ecosystems that are threatened or endangered • Area of ecosystems or habitats that are classified as threatened in national or international systems • Area of priority habitats and ecosystems for conservation at the global, regional, national, and/or local levels
	AND	
	2. Condition of rare, endemic, threatened or endangered habitats or ecosystem	• Ecological integrity index • Proportion of forest intactness areas • Disturbance level • Presence of indicator species for good habitat/ecosystem quality • Proportion of degraded habitats in relation to total
ES1: Biodiversity conservation		
ES1.12: Enhancement of rare, endemic, threatened or endangered habitats or ecosystems		

The same as per Impact ES1.11		

Carbon sequestration and storage

Forest owners looking for ES shall specify which carbon pools have been included in the measurement of the present value and the baseline value.

NOTE 1: forest carbon pools are above ground biomass, below ground biomass, deadwood (standing and lying), litter, and soil organic matter.

NOTE 2: it is important to include the same carbon pools in the present value and the baseline value. Under no circumstances can more carbon pools be included in the present value than in the baseline value.

ES2: Carbon sequestration & storage		
ES2.1: Enhancement of forest carbon stocks through afforestation, reforestation and/or restoration		
The organisation shall select at least one outcome indicator to measure the following:	1. Forest carbon stocks	• Estimated carbon stocks across the entire management unit
ES2: Carbon sequestration & storage		
ES2.2: Maintenance of forest carbon stocks through responsible forest management		
The organisation shall select at least one outcome indicator to measure the following:	1. Forest carbon stocks	• Estimated carbon stocks across the entire management unit
	AND	
	2. Carbon emissions	• Carbon emissions related to forestry operations
ES2: Carbon sequestration & storage		
ES2.3: Enhancement of forest carbon stocks through responsible forest management		
The same as for ES2.2, except required results are "Forest carbon stocks in the management unit are higher than previous measurement", "Forest carbon stocks in the management unit are higher than projected carbon stocks for the year of measurement of the present value" and "Emissions from forestry operations are lower than the reference value or the historical reference level of emissions related to forestry operations in the management unit".		
ES2: Carbon sequestration & storage		
ES2.4: Maintenance of forest carbon stocks through forest conservation or protection		
The organisation shall select at least one outcome indicator to measure the following:	1. Forest carbon stocks	• Estimated carbon stocks across the entire management unit
	AND	

	2. Carbon emissions	• Carbon emissions related to forestry operations
ES2: Carbon sequestration & storage		
ES2.5: Enhancement of forest carbon stocks through forest conservation or protection		
The same as for ES2.4, except required results are "Forest carbon stocks in the management unit are higher than previous measurement", "Forest carbon stocks in the management unit are higher than projected carbon stocks for the year of measurement of the present value" and "Emissions from forestry operations are lower than the reference value or the historical reference level of emissions related to forestry operations in the management unit".		