FOREST4EU

Connecting forestry and agroforestry partnerships across Europe

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Quantification of Carbon Stock in Sustainible Forest Managment Plan

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1. Summary

Innovations play a big role in the EU rural development policy. One of the ways of promoting innovations in EU is setting up operational groups (OGs) which are a part of the EIP-AGRI programme. They bring together various stakeholders with the aim to accelerate innovation. The goal of the project Forest4EU was to identify different OGs in EU countries, identify their innovations and classify them in five different innovation hubs (ITHubs). The 176 innovations from 86 OGs were then presented in extended summaries and put through 3 stages of evaluation (project partner, expert, and workshop evaluation). Each of the stages reduced the number of innovations down to 5 per ITHub (25 overall), leaving only the most relevant ones for the countries, where the evaluation was conducted. In the case of Slovenia, Croatia, Latvia and Portugal, one of the innovations with the best score from the final evaluation was: Carbon accounting for PES by the (Operational group) GO FOR.TRACK. The innovation presents a method of calculating carbon stock based on the forest biomass data, which could be used to calculate carbon credits and set up a market with them. This is an innovation, that could be useful for a lot of stakeholders in Slovenia.

Key words: operational groups, knowledge, innovation, carbon credits, stakeholders

2. Introduction

EU rural development policy emphasizes the importance of setting up operational groups (OGs) as one of the most important measures. These groups are at the heart of the European Partnership for Innovation in Agricultural Productivity and Sustainability, known as EIP-AGRI. The OGs within the EIP-AGRI represent communities of experts coming together in innovative projects funded by Rural Development Programs (RDPs). Their main objective is to translate innovative ideas into feasible solutions (Parzonko at al., 2022). They bring together various stakeholders of the European knowledge and innovation systems in agriculture, such as farmers, foresters, researchers, consultants, businesses, environmental and interest groups and other non-governmental organizations. They aim to accelerate innovation in agriculture, forestry, and rural areas and to find practical solutions to the challenges these actors face in their daily work (EU CAP NETWORK, b. l.).

The main objective of this policy is to promote sustainable and practical solutions to the challenges in agriculture and forestry. OGs can be defined as innovation intermediaries, which underlines their key role in knowledge transfer and experience exchange between different stakeholders (Nieto at al., 2021).

As part of the FOREST4EU project, we promote OGs for forestry and agroforestry. It is a project of the Horizon Europe 2020 program that aims to connect the existing OGs of different European countries. Through the project, we promote the transfer of knowledge and best practices between experts in the field. 16 partners from nine countries are involved in the project.

To promote innovation in agriculture and improve knowledge transfer between different regions and sectors, the establishment of interregional, cross-sectoral and innovation hubs (ITHubs) was crucial. These hubs focused on five key innovation themes that are crucial for the future of agriculture and rural areas. The five key innovation themes are (1) Wood mobilization, i.e. improving the added value of wood extraction and improving the availability of wood biomass potential from private forests; (2) Adaptation of forests to climate change, i.e. the search for new solutions that help foresters to adapt forest management to the effects of climate change; (3) Sustainable management of forests and ecosystem services, i.e. the promotion of practices that regulate the extraction of wood for other ecosystem services; (4) Other (non-timber) forest products to develop and exchange new business models for the supply of non-timber forest products; (5) Agroforestry production systems for the design and implementation of adapted policy support measures within the agroforestry production system. Innovation can be defined as the application of new ideas to the products, processes, or other aspects of the activities of a firm that lead to increased “value” (Wiltshire et al., 2023).

The aim is to facilitate inter-regional knowledge transfer, collection, exchange, and dissemination of knowledge related to innovation and to discuss the benefits of operational groups funded by the Rural Development Program and relevant to the implementation of the Green Deal, as well as to establish contacts with policy makers at local level, especially in countries where operational groups are already active.

3. Methodology

The FOREST4EU methodology follows the understanding of innovation in EIP-AGRI OGs as defined in the “Guidelines on Programming for Innovation and the Implementation of the EIP for Agricultural Productivity and Sustainability” (2013).

Thus, innovation moves beyond a specific invention or novelty by emphasising the process of applying it practically and making it a success (Weiss et al. 2020). To classify innovations in the selected EIP-AGRI OGs in

FOREST4EU, the present methodology incorporates the Commission's process- and multi-actor-centred understanding of innovation in rural development. It starts by identifying different types of innovation, thus answering the question of what the innovation is about, namely; technological, process-related, product-related, service-related, organizational, or social innovations.

All the innovations included in the project were identified and collected by the ITHub members from existing practical knowledge coming from 86 European forestry and agroforestry OGs. The OGs were identified in 10 different countries: Austria (1 OG), France (19 OGs), Germany (1 OG), Italy (11 OGs), Latvia (1 OG), the Netherlands (1 OG), Portugal (24 OGs), Spain (24 OGs), Slovenia (3 OGs) and Sweden (1 OG). Based on those innovations, the FOREST4EU consortium prepared 176 Extended Summaries (ES). Each of the Extended Summaries (ES) presents a short summary of one innovation collected in the project.

All Horizon multi-actor projects and thematic networks, as well as all OGs, use a common format developed by EIP-AGRI Network to provide farmers, foresters, advisers, or other interested stakeholders with concise and short practical information (PAs). As explained by the EIP-AGRI Network, the use of this common format facilitates the exchange of knowledge, but also the contact between different practitioners and stakeholders.

3.1 Collection of existing practical knowledge (innovation) from forestry and agroforestry Operational Group

Following the methodology developed by Steinbeis Europa Zentrum (S2i), in April 2023 the members of the five ITHubs identified the main challenges and needs faced by the foresters and other practitioners regarding the specific topics of 5 established ITHubs.

Based on these findings, the ITHubs collected practical knowledge on the innovations generated by selected EIP-AGRI OGs. These innovations tackle identified problems and needs. The collection of the innovations was carried out through the dedicated analysis of the outcomes of the corresponding OGs belonging to each ITHub. This was done in agreement and with the collaboration of the coordinators of all selected OGs.

3.2 Elaboration of Extended Summaries

Based on this collected material and the direct exchange with the OGs, the members of the different ITHubs elaborated an ES in English (2 – 4 pages) for each identified innovation. For this purpose, a dedicated template was developed by S2i. It is important to highlight that the results from forestry and agroforestry OGs are only available in the national language.

FOREST4EU will make this practical knowledge on innovations available to a broader public across Europe, improving the transfer of practical knowledge from the local/national level to the EU level.

3.3 Preparation of Practice Abstracts

From March 2024, under the coordination of S2i, all the members of the five ITHubs participate in the elaboration of the PAs based on the FOREST4EU ES. Each PA includes a description of the innovation, practical recommendations (e.g. what would be the main added value/benefit/opportunities to the end-user if the innovation is implemented? How can the practitioner make use of the innovation?) and contact information. All produced PA are going to be available in English and in one of the national languages from the consortium (Croatian, Finish, French, German, Italian, Latvian, Portuguese, Slovenian and Spanish).

3.4 Innovation selection process in Slovenia

Each partner evaluated the 175 innovations according to their relevance from an EU and national perspective. After receiving the classification results from each of the participating countries, the 20 highest-ranking innovations per ITHub were selected (100 overall). In the next phase, national experts were involved to evaluate 20 innovations per ITHub. Based on experts in a new selection process, which involved experts in the field of different ITHubs. This selection process in Slovenia involved 12 experts who identified the 10 most relevant innovations from national perspective. These 10 most relevant innovations per ITHub were then presented at a workshop that was organized in Slovenia. The workshop took place at the SFI and was attended by approximately 50 people from different target groups. For a better understanding of innovations, participants were presented with short definitions with practical examples of different types of innovation. After the presentation of the innovations, the participants evaluated the innovations, and the data was collected via an online survey. In Slovenia, we selected 5 innovations per ITHub, 25 overall.

The selected innovations are presented in a table below.

Table 1. Selected innovations from 5 ITHubs in a workshop with different participants

ITHUB 1: Wood mobilization	*(1) Creating Your Own Estate Plan with Online Portal MojGozdar; (2) A System for Quality Assessment of Forestry Contractors; (3) Assessment of Costs in Harvesting Systems using an Web-based Tool (WoodChainManager); (4) LVL (Laminated Veneer Lumber) of beech trees; (5) Online tool for quality classification of round-wood.*
ITHUB 2: Adaptation of forests to climate change	*(1) Educational module "foresters, it's your turn to play"; (2) Application of SlideforMap for the hydrological risk assessment in sustainable managed forests; (3) Bioclimsol : a decision support system integrating future climate and ground conditions; (4) UAV and multispectral camera to map stressed forest area (5) "The "sustainable bee forest" concept and implementation.*
ITHUB 3: Sustainable management of forests and ecosystem services	*(1) Carbon accounting for payments for enviromental services (PES); (2) The ARCHI method: a tool for diagnosing the vitality of trees; (3) Index of Biodiversity Potential (IBP): a practical tool for forest managers; (4) Developing a Novel Martelloscope for Assessing Biodiversity and Growing Stock Volume with the aid of a Digital Twin; (5) Support multi-object forest management plans through easy-access information.*

ITHUB 4: Other (non-timber) forest products	*(1) Establishing new business models with NWFP,* *(2) Biological Treatment of cancer chestmenut (Cryphonectria parasitica) in Portugal;* *(3) Mobile charcoal pile prototype for biochar production in situ;* *(4) Valorization of a neglected plant;* *(5) Post-harvest coatings from mushroom by products*
ITHUB 5: Agroforestry	*(1) “Agroforestry in Austria” Network* *(2) "Criteria and indicators for the certification of the sustainable management of anagroforestry system PEFC";* *(3) Practitioner-oriented consulting for agroforestry systems in Austria;* *(4) "A feasible step-by-step plan with practical guidelines and concrete designs to enable the application of agroforestry on farms";* *(5) Local densified log industry.*

One of the innovations that was recognized as the most interesting was the innovation named “Carbon accounting for PES,” which was introduced by the GO FOR.TRACK. The innovation was also recognized as important at workshops in other countries, such as Croatia, Latvia, and Spain. The mentioned OG and innovation are presented in more detail in the following section.

4. Development of a Decision Support System for Continuous Mapping of Forest Resources (GO FOR.TRACK)

Forests provide more than just timber and non-timber materials; they provide a wide range of additional services, including creating habitats for biodiversity, purifying water, and regulating floods and climate (Fortrack, b.l.). Their ability to sequester carbon, provide cooling and supply renewable raw materials, food and medicines is essential for combating climate change, transitioning to a circular bioeconomy, and promoting the overall health of society. The economic sustainability of the EU forest sector remains a fundamental aspect of sustainable forest management. Moreover, this economic sustainability is crucial for maintaining the various benefits that forests provide to society, for securing the livelihoods of rural communities. Both public and private payments for forest ecosystem services offer an alternative to ensure the financing of multifunctional and protective forest management and the sustainable maintenance of ecosystem services. In this context, it is important to develop methods to quantify these ecosystem services. Among the services for which there is a potential market, carbon is the most developed.

The objective of GO FOR.TRACK was to develop and test a decision support system that enables the implementation of precision silviculture practices in a simple and intuitive way when updating and creating management plans.

With new technological tools, this system strengthens the market power of private forest owners, forestry companies, public managers, service and marketing companies and independent entrepreneurs and facilitates the conservation of Calabria's forest heritage. It enables the transfer of research techniques into practice, including GIS technologies, remote sensing, spatial modeling and computer algorithms. It allows companies to easily upload forest inventory plots and automatically generate forest resource maps and topographic data (e.g. elevation, slope, accessibility).

Thematic maps and algorithms can be used to support decision-making:

- Quantify Forest variables,

- Support the preparation of forest management plans and permit applications for forestry operations based on a specific form using thematic maps and data collected on the ground,
- Keeping a record of the company's interventions and forestry operations using a computerized and cartographic database,
- Collecting data on interventions carried out according to the management plans to update the company information.

This fundamentally changes the method of drawing up management plans, as revisions provide updated information, reduce costs and thus increase the market power of companies.

The main expected impact is to propose a change in the approach to forest management using an information system that allows the simple and automatic integration of different databases. A simple system has been developed that makes it easy to find information and documents at company level. These new technologies help increase the economic added value of forestry activities by reducing the costs of drawing up and controlling management plans, promoting the integration of the estimation of multiple ecosystem services and offering a new perspective on traditional forest management, which primarily focuses only on quantifying the growing stock volume.

The implementation of the decision support system provides access to technologies that were unavailable due to a lack of programming skills among companies and technicians in the sector. Specifically, changes are expected throughout the community that manages the forestry heritage of the Calabria region, with potential socio-economic impacts that enable:

- Changes in the way forest managers organize their routine work;
- a more sustainable use of forest resources based on the indicators defined by Forest Europe, the former Ministerial Conference for the Protection of Forests in Europe, which can be easily estimated using the information system;
- Change in the income level of the forest sector due to cost savings in the collection of forest data.

The main expected impact of this project network is that the proposed methodologies could improve the competitiveness of the forestry sector in the Calabria region by reducing the cost of obtaining information, which is currently very high with traditional tools. Furthermore, the system module implemented at regional level represents a first information base accessible to all companies and technicians, which will bring about a profound change in the acquisition of information on the forest systems of Tuscany and in particular in all the municipalities of the Calabria region.

In Italy, there is no formalized National Carbon Market yet, and the activities take place mainly in the voluntary sector. In this scenario, the calculation of "Business as Usual" (BAU) and the compensation resulting from management is crucial.

To have a picture of BAU, it is important to find methods that are as standardized as possible and to quantify carbon accurately. In this case, using biomass data from the plot integrating them with remote sensing Satellite (Sentinel-2 satellite) data using area-based approach a biomass map was obtained and then convert using the national conversion factor of 0.5 into carbon. This data was initially not used for participation in the carbon credit market, but only to provide a reference framework for BAU and to initiate proposed management changes, with the intention of calculating offsets at a later stage.

5. Innovation: Carbon accounting for PES

Terrestrial ecosystems, including forests, play an important role in the carbon cycle, acting as both sinks and sources of carbon dioxide, depending on their conditions, the management practices applied and the anthropogenic and natural interactions within the systems. International technical and political bodies dealing with climate change and the problem of increasing carbon emissions, starting from the Rio de Janeiro Conference in 1992 and the well-known Kyoto Protocol of 1997, ratified by Italy at both European and national level (Law no. 10 of June 1, 2002), have created a complex system for calculating and evaluating emissions. This system is regularly reviewed and updated at the annual Conferences of the Parties (COP/MOP).

In this context, it is essential to consider the carbon credits stored by forest ecosystems. It is also crucial to quantify the potential increases and decreases in CO_2 that can be used by states to reduce the costs associated with exceeding the emission limits set by the Kyoto Protocol. The Kyoto Agreement and its subsequent developments have led to the definition and regulation of "carbon trading," a market for carbon credits that broadens the perspective of energy plan development from the international to the national to the regional and sub-regional level by enabling the trading of carbon credits. In addition, there is carbon offsetting where carbon dioxide and/or greenhouse gas emissions are reduced to compensate for emissions caused elsewhere.

In this context, a distinction is made between two main markets:

- The official market
- The voluntary market

In this market, carbon credits are traded to reduce greenhouse gas emissions, one of the main causes of climate change. A carbon credit is an "intangible" unit generated by an activity that absorbs carbon dioxide or prevents greenhouse gas emissions. The key feature of the carbon credit market is that the credits are generated by local action to reduce emissions and not by action in other countries.

5.1 The Official Market

The official market for Kyoto covers all types of credits, including RMUs from land use, land-use change and forestry (LULUCF). The cap is the minimum amount that the state guarantees in non-transferable AAUs, CERs, ERUs and RMUs to maintain the reserve for the target period. The EU ETS includes LULUCF credits, including tCER/lCER from AR projects under the CDM.

Since 2008, Italy has used carbon credits from its forests for the international targets of the Kyoto Protocol. Currently, it is not possible to cooperate with an individual forest manager/owner such as GO in the official market and there is no mechanism for compensating owners for carbon credits in Italy yet.

5.2 *The voluntary market*

The voluntary carbon market is interesting for forest owners and companies in the GO complex because it is based on voluntary rules and does not set targets. The carbon resistance arising from management against the standard framework needs to be quantified. This can be difficult, but some certification operators such as PEFC, FSC and VERRA offer methodologies for calculating offsets. The scheme provides a framework for quantifying offsets that can be used for commercial or charitable purposes at a price of between €5.50 and €30 per tonne of CO_2.

Although each certification body uses different methodologies to quantify offsets, there are formal standards for their quantification based on collaboration between emitters, regulators, environmentalists and project developers. These standards include the Verified Carbon Standard, Green-e Climate and the Chicago Climate Exchange, which extend the requirements of the Kyoto Protocol's CDM. When referring to CDM projects, only AR activities are eligible, while at national level this also includes LULUCF activities, which are defined in Articles 3.3 and 3.4 of the Kyoto Protocol and in Decision 2/CMP7.

Within the two forests of the companies participating in the OG, the following compensation measures are possible:

- IFM (Improved Forest Management)

If the complex of the two forestry companies wants to enter the voluntary intervention market, it must comply with some technical rules:

- Additionality and intentionality must be calculated under normal management conditions. This means that they are calculated with a specific project that is different from what is normally done (BAU). Only activities that lead to emission reductions and increased storage (additional) compared to BAU can be considered,
- The absorption effects must be permanent over time. Risks associated with fires, storms and pest infestations must always be conservative,

- There should be a balance between investment in absorption and investment in energy conservation and conversion, including for those who will purchase the credits,
- Additionalities must be measured, and it is better if this is done with verifiable methodological standards.

5.3 Methodology of the innovation

To develop a map of forest biomass, it is crucial to have access to different types of information. In the development process, we used the information normally available for forest management plans in the two forests managed by GO FOR.TRACK's two companies partner of the GO FOR.TRACK. The company has a GNSS receiver surveyed plot with GNSS center where all trees have been measured and has access to information on the volume of the growing stock. We used the information about the field plot to develop a growing stock map based on an area-based method using Sentinel-2 imagery as predictive variables. On this basis, a 23x23 m growth stock map was developed (Giannetti et al., 2022).

The growing stock volume map(GSV) was then converted into a biomass map. Two key pieces of information are needed to convert the GSV into biomass: (1) the spatial distribution of forest types; (2) biomass expansion factors (BEF) and wood basis densities (WBD) for each forest type. Since, the GSV map is a continuous spatial map, to convert it into biomass, we used the detailed spatial forest type map developed by the two companies in the context of their forest management plans as geographic layer to convert GSV in biomass following the formula of Federici et al. (2008):

$$BIO = GSV * BEF * WDB$$

The meaning of the equation; GSV is the pixel value of growing stock volume (m^3 /ha), BEF is the biomass expansion factor of each forest type and WBD is the wood basic density of each forest type.

The obtained biomass map has pixels of 23 m × 23 m, indicating the forest biomass in t/ha.

To convert the biomass to carbon, we used the conversion factor 0.5 and obtained the carbon map (t/ha), which is the starting point for the BAU (Giannetti et al., 2022).

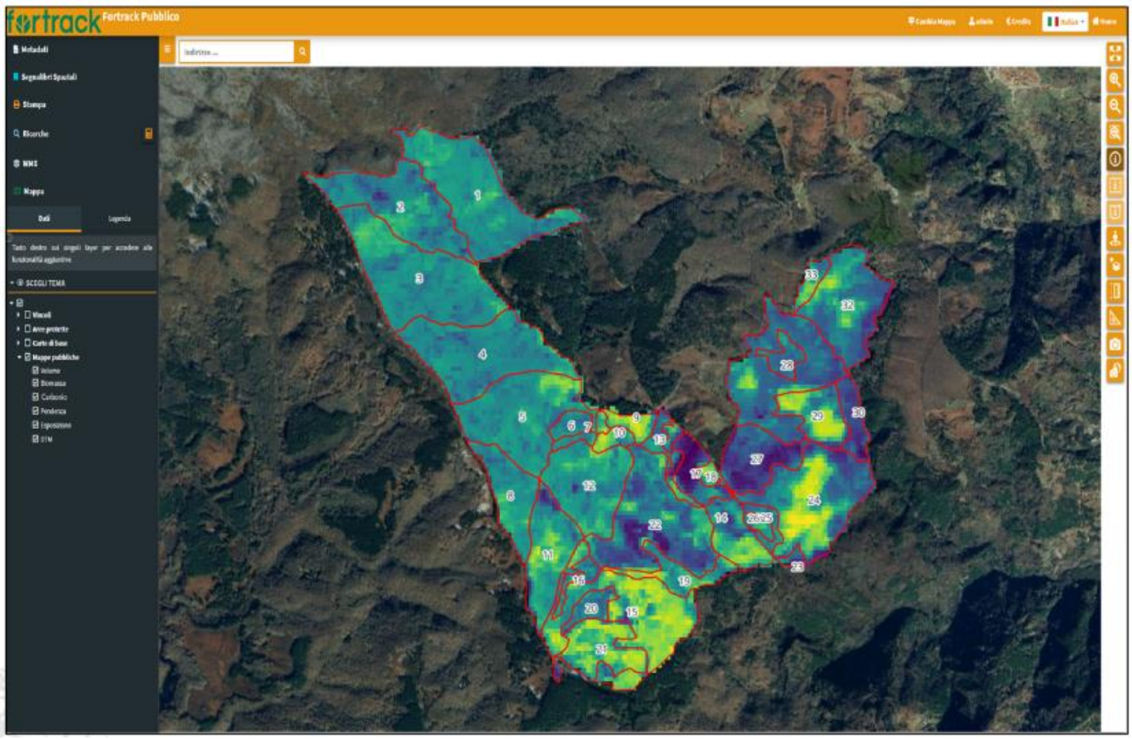

Figure 1.Details of the growing stock map of one area of the GO implemented in the decisional support system of GO Fortrack

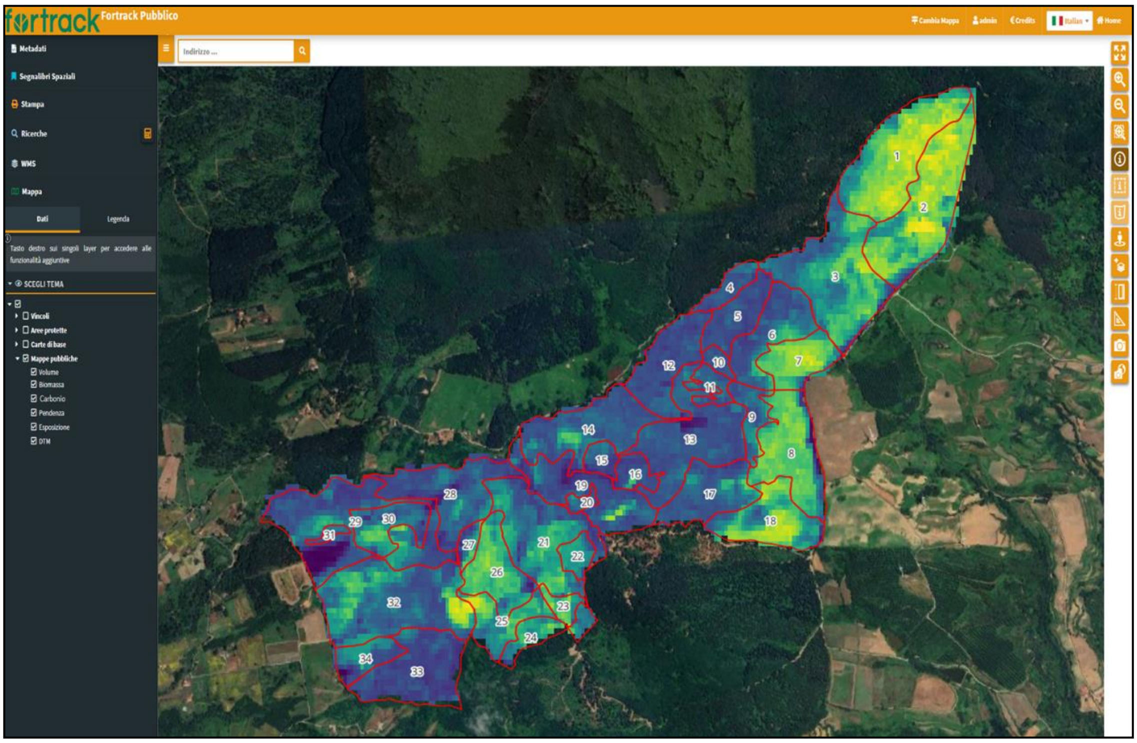

Figure 2. Details of the carbon of one area of the GO implemented in the decisional support system of GO Fortrack

To obtain a map of ecosystem services for carbon assimilation of forest formation, the approach of Federici et al. (2008) was developed for Italian forests. According to this approach, the wood stock was converted into aboveground biomass (t/ha) and aboveground biomass (t/ha) and then into carbon, according to the scheme in Figure 3 and the species-specific ratios listed in Table 1.

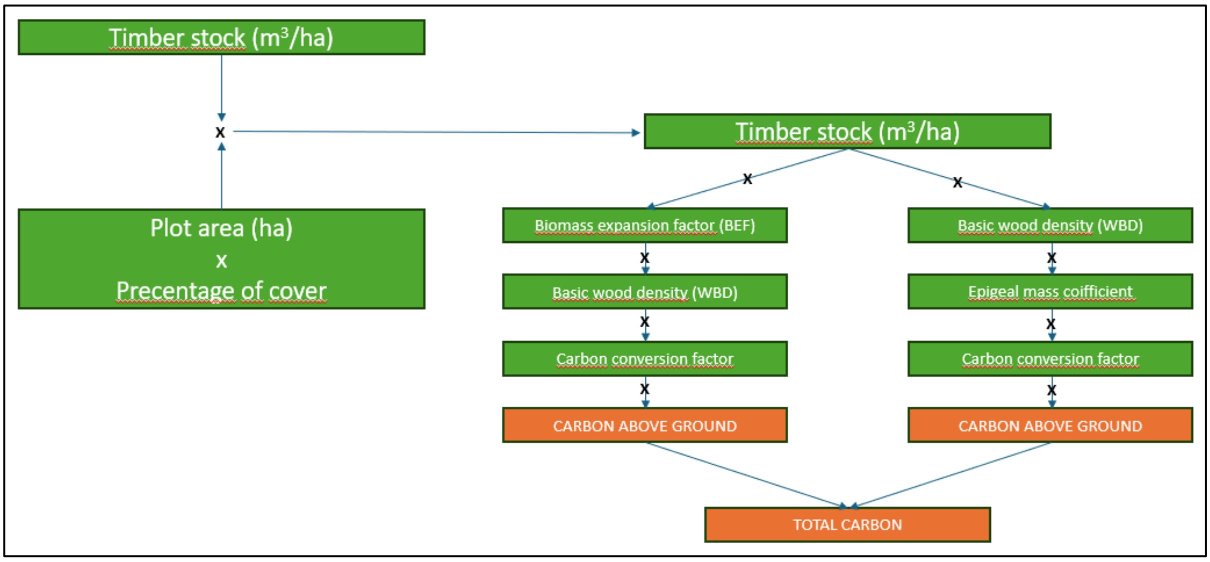

Figure 3. Calculation scheme for the carbon assimilated by the forests of the upper Bidente Ridracoli

Table 2. Biomass expansion factors (BEF), wood basal density (WBD) and the ratio of belowground to aboveground biomass (root/shoot ratio - R) according to management type and dominant species, derived from the work of Federici et al. (2008).

Forest managment type	Forest species	Biomass expansion factor (BEF) Value of aboveground biomass/woody volume	Basal density of wood (WBD) Anander weight (t)/ fresh wood volume (m^3)	(R) Weight of underground biomass/Weight of woody biomass
Tall trunk	European spruce (Picea abies)	1.29	0.38	0.29
	Silver fir (Abiea alba)	1.34	0.38	0.28
	Mountain pines (Pinus nigra, Pino Silvestris, pino Wallichiana)	1.33	0.47	0.36
	Other conifere (Greek fir, larch, juniper)	1.37	0.43	0.29
	European beech (Fagus Sylvatica)	1.36	0.61	0.20
	Turkey oak (Quercus cerris)	1.45	0.69	0.24
	Other oaks	1.42	0.67	0.20
	Sweet chestnut (Castanea sativa)	1.33	0.49	0.28
	Other broadleaves (Carpino, Ciliegio)	1.47	0.53	0.24

Coppice	European beech (Fagus Sylvatica)	1.36	0.61	0.20
	Sweet chestnut (Castanea sativa)	1.33	0.46	0.28
	Black Hornbeam and White Hornbeam	1.28	0.66	0.28
	Turkey oak (Quercus cerris)	1.23	0.69	0.24
	Downy oak (Quercus pubescens)	1.23	0.69	0.24
	Other oaks	1.39	0.65	0.20
	Other broad-leaved trees (Major Ash, Manna Ash)	1.53	0.53	0.29
Plantations	Conifers (Duglasia)	1.41	0.43	0.29

In more detail, the above-ground biomass of each forest plot was calculated using the following function:

$$Above - ground\ biomass = wood\ stock\ m^3/ha\ * (forest\ plot\ area\ ha * percent\ of\ cover) * BEF * WDB$$

The meaning of the equation: Woody Stock represents the GSV[m^3/ ha^{-1}]; Forest plot area is the area covered by the stand in ha, Percent of Cover is the percentage of plot coverage by forest species, BEF is the biomass expansion factor, which converts wood volume into above-ground woody biomass of the dominant species; WBD is the basic wood density (t/m^3) of the dominant species.

BEFs were obtained for each forest plot based on dominant species using the preliminary results of the RiselvItalia project carried out by ISAFA (ISAFA 2004), while the base densities for conversions from fresh volume to dry weight were derived for each dominant species by Giordano (1988) (Table 1).

$$Below - ground\ biomass = wood\ stock\ \frac{m^3}{ha} * (forest\ plot\ area\ ha * percent\ of\ cover) * WDB * R$$

The meaning of the equation; Woody Stock is the volume of wood [m^3/ha]; Plot area is the area covered by the plot in ha. Coverage percentage is the percentage of plot coverage with forest species; WBD is the basic wood density (t/m^3) of the dominant species, and the R coefficient converts the woody stock to the belowground biomass of the dominant species. R conversion factors were obtained for each dominant species using preliminary results from the RiselvItalia project by ISAFA (ISAFA 2004), while base densities for fresh volume to dry weight conversions were derived for each forest species from Giordano (1988) (Table 1).

From the forest biomass maps thus obtained, carbon assimilation maps were created using the conversion factor calculated on the basis of the EN-16449 regulation, which was also used by Federici et al. (2008) at the Italian level. As stated in the EN-16449 regulation of 2014, wood contains different amounts of cellulose (between 40% and 55%), hemicellulose (between 12% and 15%), lignin (between 15% and 30%) and extractives (between 2% and 15%) depending on the tree species. Based on the composition of these compounds, it can be assumed that the wood has an approximate average carbon content of about 50 % of the dry weight of the wood. In accordance with the procedure described in Federici et al. (2008) and the EN-16449 (2014) standard, a conversion factor of 0.5 is used in this plan as the value for the carbon content of the wood biomass.

Aboveground biomass, belowground biomass, aboveground assimilated carbon and belowground assimilated carbon were calculated for each forest unit using the following method. Total assimilated carbon was calculated by adding epigeal assimilated carbon and hypogeal assimilated carbon.

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