GREENChainSAW4Life

Project No. LIFE18 CCM/IT/001193

"GREEN energy and smart forest supply CHAIN as driversS for A mountain action plan toWards climate change"

Deliverable DL. C5.4

Analysis of combined Lidar application in unmanaged dense forest stands and Validation of carbon credits

Action Number and Title	Selection of Demo Forest Plots and Pilot Forest Harvesting.
Task	C5.4 Analysis of combined Lidar application in unmanaged dense forest stands and Validation of carbon credits
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SUMMARY

1 INTRODUCTION

This report is part of the European project GreenChainSAW4Life, funded under the Life Action for Climate Program. GreenChainSAw4Life aims to contribute to the adaptation and mitigation of climate change in mountain areas through the development of a "participatory" model of "climate smart" forest management, which implies the implicit and explicit knowledge of all stakeholders in the planning and management of processes for the enhancement of local forest resources. Among the project activities, Action C5 included the implementation of pilot forestry operations, with the involvement of public and private forest owners, to allocate retraceable timber in cascading uses. Walden s.r.l., as an associated beneficiary of the project was responsible, within Action C5, for identifying areas of interest, contacting and animating forest properties, and designing and directing silvicultural interventions. The pilot forest plots described below were used to test climate smart forestry approaches. To this end, we applied climate smart forestry approaches to the most common forest type most at risk for climate change in the Po Valley: unmanaged chestnut coppices mixed with other broadleaf species. The proposed approach involved one or two thinnings every 10 to 15 years, with the goal of ensuring the transition of coppice into tall forest, ultimately increasing the complexity of forest plots. Specifically, the objectives of the thinning operations were to (i) promote the regeneration of local species; (ii) decrease fire risk; and (iii) increase the complexity of the forest structure. In addition to the silvicultural objectives mentioned above, this approach aims to improve timber quality over time. Finally, the different ecosystem services that the managed forest is able to provide were accounted for, e.g., to protect biodiversity, the Index of Biodiversity Potential (IBP) was used, or through more conservative intervention, it was possible to reduce carbon drawdown during utilizations and regenerate forests that can absorb more in the future. This report explains the approaches used and compares the different methodologies used to account for them, describing what were the strengths, critical issues that emerged, and what future approaches can be used to manage forests to increase the ecosystem services they produce.

1.1 CONFIDENTIALITY

This document is the result of a study and research process involving public (Comune di Barge and Unione Montana dei Comuni del Monviso) and private entities (Walden SRL), all information contained is the property of the project partners. The document is intended for public access but is the property of Walden SRL, the Municipality of Barge and Unione Montana dei Comuni del Monviso.

2 PILOT FOREST PLOTS

2.1 FOREST PLOT "A" - PAGNO

The area of intervention of forest plot "A" is located in the municipality of Pagno (CN), south - east of the town, with development downstream in the direction west of the Sanctuary of Santa Cristina di Verzuolo. The area is developed at an altitude between 800 and 850 m a.s.l., with an average slope of 14° (with marked differences between sub-sloping areas and very steep slopes) and general North - West exposure. The total area of intervention, gross of any tares is 5.15

ha. The stand was homogeneous and belonged to the forest type[1] CA20C - mesoneutrophilous chestnut forest in Alpine Salvia glutinosa - var. with Beech*.* This was an aged chestnut coppice with average age of suckers of *Castanea sativa* and *Fagus sylvatica* of about 40 years; individuals of *Quercus petraea, Prunus avium, Sorbus aria and Sorbus aucuparia* were also present sporadically. Decay and crashing of chestnut stumps, attributable to silvicultural abandonment of the chestnut grove and the wide spread of cortical canker generated by the pathogen *Cryphonectria parasitica, were* also noted*. The* table below shows the main average dendrometric parameters of the pre-intervention stand per hectare, divided by species coded as follows: BP - *Betula pendula*, CS - *Castanea sativa*, FS - *Fagus sylvatica*, QR - *Quercus petraea* and SA - *Sorbus aria.*

Specie	N°/ha	G (m^2/ha)	V (m^3/ha)
BP	50,5	2,4	17,9
CS	613,8	31,9	245,3
FS	486,0	13,3	112,7
QR	14,9	1,1	10,2
SA	14,9	0,2	1,1
	1180,1	**48,9**	**387,3**

Table 1: Main dendrometric stand data referred to hectare.

In order to know the biodiversity of the stand and to direct silvicultural intervention to maintain or improve its natural characteristics, the index of potential biodiversity (IBP) has been applied. The IBP[2] was created in France in 2008 as part of a national research and development program conducted by the *Centre National de la Propriété forestière* (CNPF). In order to maintain the required level of biodiversity, a total of 75 plants were marked; the maintenance of these specimens was verified during and after the work was carried out.

The silvicultural objective sought in the long term is to obtain a forest government where the gamic component was represented mainly by the species *Fagus sylvatica, Quercus petraea* and *Prunus avium*, with a residual component of mainly agamic origin of *Castanea sativa.* In order to achieve this goal, two interventions were planned. The first, carried out within the framework of this project, involved chestnut stumps that were partly coppiced and partly started up to tall trees by enfranchising 1-2 suckers per stump. Action was mainly taken against competitors of the valuable broadleaf trees, freeing them and creating renewal holes for them. In the second intervention, planned in about 15 years, the remaining stumps will be enfranchised by releasing 1-2 suckers and the mature suckers already enfranchised in the first intervention will be taken; a part of the take may also be the candidate individuals of the mature forest stand. Both interventions are configured as intercropping, releasing at the end of the work a cover of more than 50 percent as required by Article 55 of the Forestry Regulations.

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[1] CAMERANO P., GOTTERO F., TERZUOLO P.G., VARESE P. - IPLA S.p.A., Forest types of Piedmont. Piedmont Region, Blu Editions, Turin 2008, pp. 216.

[2] LARRIEU, L., GONIN, P. 2008. L'indice de Biodiversité Potentielle (IBP): une méthode simple et rapide pour évaluer la biodiversité potentielle des peuplements forestiers. Revue Forestière Française (6), pp. 727-748.

The timber retracted from utilization was stored in Saluzzo (CN) in a yard owned by the municipality near the Foro Boario. Utilization accounted for approximately 27.7 percent of the total volume of the stand with a total of 4,250 quintals of timber. Of this about 27% was released to the landowner for land concession, while the remaining 3,092.30 q.li was sold by the Unione Montana dei Comuni del Monviso through public auction. The winning company, on 25/08/2023, turned out to be Monbracco Energy SRL with a bid of €4.33/sq.le for a total of €13,389.66.

Despite the fact that the intervention was, in principle, carried out according to the design indications, the volume exbuscated was less than expected. This difference is due to a number of factors that did not allow for a correct estimate of the quantities exbuscated, prime among them being the large amount of standing and dead dry timber on the ground, removed during the execution of the work but not accounted for in the estimate, as well as the different specific weight of the dry timber, which was much lower than the green timber. Further critical issues are related to the poor quality of the timber, which being mostly chestnut also had problems with stem onioning, this resulted in its use totally oriented to energy production, partly as wood chips and partly as firewood.

The intervention had a positive outcome and the set objectives were achieved. In particular, there were positive effects on the enhancement of ecosystem services; the biodiversity present was maintained and increased as predicted by the IBP index. The removal of almost all dry and dead wood on the ground has significantly decreased the fuel load present in the area and thus the fire risk has been mitigated furthermore compared to ordinary harvesting, a less invasive and impactful intervention has been designed, therefore this has allowed for less harvesting and - it is hypothesized - greater future carbon accumulation within the stand. Finally, the restoration and maintenance of the existing road system allows for greater tourist enjoyment of the area and also will allow for future forest improvement interventions.

2.2 FOREST PLOT "B" - BARGE

The intervention area of forest plot "B" is located in the South - East of the municipality of Barge (CN) upstream of the hamlet Capoloira. The area is developed at an average altitude of 580 m above sea level with southwest exposure. The area is strongly conditioned by abandoned terraces used for agricultural purposes, the presence of artifacts and rural dwellings-"Ciabot" of historical-cultural interest-are also highlighted. The area of intervention involves private properties for 3.92 hectares under the management of the Infernotto Valley Land Association and public properties of the municipality of Barge for 0.88 hectares. The total area of intervention thus consists of 4.8 hectares.

The stand was heterogeneous and belonged to the forest type CA20B-Mesoneutrophilous chestnut forest in Alpine *Salvia glutinosa* var. with mixed broadleaf trees. The chestnut coppice was found to be very aged with average sucker age of more than 45 years. The gamic component of the stand consisted of adult specimens of *Quercus petraea* constituting the dominant storey and a portion of pioneer broadleaf trees represented especially by *Betula pendula* in the barrens. The stand was also characterized by the scrub-like spread of *Robinia pseudoacacia* with greater density in the eastern portion of the slope. The herbaceous layer had extensive development of bramble and bracken. Decay and overturning of chestnut stumps, which can be attributed to the silvicultural abandonment of the chestnut forest, and the wide spread of cortical canker generated by the pathogen *Cryphonectria parasitica* were also noted. The table below shows the main average dendrometric parameters of the stand per hectare, over the entire net area and in percentage, divided by species coded as follows: AR - Shrubs, BP - *Betula pendula*, CS - *Castanea sativa*, QR - *Quercus petraea*, RP - *Robinia pseudoacacia and* SA - *Sorbus aria.*

Species	N°ha	G/ha (m)^2	V/ha (m)^3
AR	75	0,7	3,4
BP	181	4,2	27,52
CS	549	26,7	196,54
QR	116	9,6	96,22
RP	192	3,5	22,58
SA	177	1,4	7,49
Tot	**1290**	**46,1**	**353,76**

Table 2: Main dendrometric stand data referred to hectare.

In order to know the biodiversity of the stand and to direct silvicultural intervention to maintain or improve its natural characteristics, the index of potential biodiversity (IBP) was applied. Due to the results obtained from the application of this index, in order to maintain the required level of biodiversity, a total of 64 plants were marked and maintained during the execution of the work.

The main objective of the intervention was to enhance the tourist-recreational function of the site, creating the initial conditions to be able to improve the internal walkability of areas with the presence of historical-cultural artifacts, reduce the risk of crashes and damage to the artifacts themselves, contain invasive species, and maintain or improve potential biodiversity. Due to the high prevalence of brambles and locust trees, achieving improved usability of the area will, however, be linked to the planning of a second intervention to contain and manage the herbaceous/arbustive component. The silvicultural objective sought in the long term is to obtain a high forest government where the gamic component is mainly represented by *Quercus petraea* species and valuable broadleaf trees such as *Prunus avium* and *Sorbus Aria*, with a residual component of mainly agamic origin of *Castanea sativa.* *In order to* pursue this objective, especially in the area of greatest tourist-recreational interest (areas bordering the pathways and the main "Ciabot") a thinning from below was carried out aimed at enhancing *Quercus petraea* specimens and in general noble broadleaf trees such as *Sorbus aria and Prunus avium.* The chestnut coppice component was coppiced or converted to tall stem by releasing 1-2 suckers per stump. The intervention is in the form of an intercropping and at the end of the work more than 50 percent cover was released as required by Article 55 of the Forestry Regulations[3] .
Data on the actual drawdown of the intervention are given below.

Assortments	% on the Tot.	m^3	q
Wood chips	46%	231,88	2.087
Ardere	54%	274,11	2.467

[3] Forestry regulations implementing Article 13 of Regional Law No. 4 of February 10, 2009

	Tot.	**506**	**4.554**

Table 3: Assortments noted by the company after the execution of the intervention.

The execution of the work was carried out according to the design directions, although these had to vary drastically depending on the logging system. In the executive design, the use of the cable crane was not planned. Using this system required the construction of new temporary logging tracks as well as the execution of hammering along the logging lines of the cable crane, which had to be implemented when the cable crane was installed. For these reasons, it was necessary to carry out numerous inspections during the execution of the work. Additional critical issues were related to the poor quality of the timber. The stand had large quantities of dry wood, often crashed to the ground. This resulted in its use totally oriented to energy production, partly as wood chips and partly as firewood.

Despite the critical issues that emerged, the intervention was successful and the objectives set were achieved. The work was carried out correctly, and the negative effects on soil and water regulation were minimal. The use of the cable crane made it possible to carry out logging on the entire site, avoiding accumulation of timber on the ground. This reduced the risk of forest fires in the area, as well as the removal of almost all dry and dead timber on the ground. The biodiversity present has been maintained and increased as required by the IBP index, and the restoration and maintenance of the existing road system allows greater tourist enjoyment of the area and access to the "Ciabot," a building of special historical interest.

In order to pursue the objectives set, it will be necessary to contain the development of bramble and bracken, which are already strongly developed on much of the stand area, and of young locust tree suckers, it will therefore be necessary to plan an intervention of containment and management of the herbaceous/arbustive component in the areas of greatest fruitive interest. Among the implementable interventions, periodic sheep/goat grazing of the area is conceivable.

3 ESTIMATION OF CARBON STORAGE

Following the logging operations, the carbon stock related to the lower removals from the forest use performed compared to traditional logging methods was calculated. Two different calculation methodologies detailed below were used for counting:

1) "D.G.R. No. 24-4638 of February 6, 2017 - Provisions for the development of the voluntary market for carbon credits from forestry in the Piedmont Region, Annex A Voluntary carbon credits from forest management - guidelines for the Piedmont Region."
2) "Carbon Accounting Tool," developed in WP C4 of this LIFE project.

It is emphasized that, unlike in the project proposal initially submitted for the Life climate action call, the use of Lidar for measuring carbon stock effects was excluded because A) satellite imagery is not of sufficient resolution to be used on small-scale interventions such as the one proposed, and B) the use of handheld laser scanners was found, from initial surveys and tests conducted during Action C2, to be still too inefficient.

3.1 METHODOLOGY 1 - PROVISIONS FOR THE DEVELOPMENT OF THE VOLUNTARY MARKET FOR FORESTRY CARBON CREDITS IN THE PIEDMONT REGION

The guidelines developed by the Piedmont region, in order to quantify the tons of **CO_{2eq}** saved, call for accounting for carbon not emitted due to the application of a more conservative silvicultural practice than ordinary practice and forest regulation. The range in which there is an opportunity to count this **CO_{2eq}** savings is between the ordinary drawdown practice and a minimum drawdown defined for each type of silvicultural intervention in relation to forest type and governance form. An illustrative graph is given below.

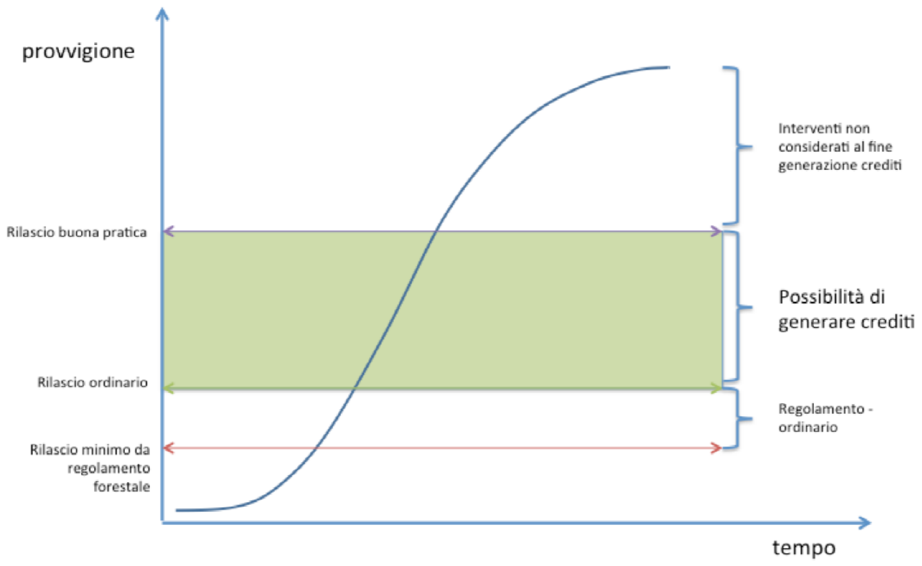


Figure 1: Graph showing the accounting scheme of CO2eq stocks in relation to the lower provision drawdown than issued by Reg. For. and ordinary practices of the Piedmont Region. Image from "D.G.R. No. 24-4638 of February 6, 2017 - Provisions for the development of the voluntary market for carbon credits from forestry in the Piedmont Region, Annex A (Voluntary carbon credits from forest management - guidelines for the Piedmont Region."

For high forest startups in chestnut and robinia groves-the case of the Pagno plot-the guidelines state the following:

Forma di governo	Intervento	% copertura da rilasciare da regolamento	prelievo possibile da regolamento forestale (% volume)	prelievo ordinario (% volume)	% copertura da rilasciare da buona pratica	prelievo buona pratica (% volume)
ROBINIETI CASTAGNETI non definita	taglio di avviamento a fustaia	50%	55%	50	65-70%	35%

For cuts within the mixed-government Barge lot case, the guidelines state the following:

Forma di governo	Intervento	% copertura da rilasciare da regolamento	prelievo possibile da regolamento forestale (% volume)	prelievo ordinario (% volume)	% copertura da rilasciare da buona pratica	prelievo buona pratica (% volume)
Governo misto	Governo misto	40%	60%	50%	55%-65%	40%
	taglio di avviamento a fustaia	50%	55%	50%	65%-75%	30%

Table 4: Guidelines for CO2eq counts extracted from "D.G.R. No. 24-4638 of February 6, 2017 - Provisions for the development of the voluntary market for carbon credits from forestry in the Piedmont Region, Annex A (Voluntary carbon credits from forest management - guidelines for the Piedmont Region"

In order to calculate the CO_2 equivalent, the following formula is applied to transform the woody mass into the mass of **CO eq:** $_2$

$$CO_{2eq} = (V*D*BEFS) * (1+R) *CF * 3.67$$

Where:

- CO_{2eq} is the CO_2 stored in the biomass of a forest initiated to the stem side;
- **V** is the volume of timber saved through the application of good practice, expressed in cubic meters m /ha;[3]
- **D** basal density of wood expressed in t ss/m3;
- **BEF_S**) biomass expansion factor including bark, leaf mass and blastometry (according to the "*NFAP for Italy - 2019*[4] " is 1.4);
- **R** dimensionless hypogean/epigeal biomass ratio (according to "*NFAP for Italy - 2019*" is 0.24);
- **CF** carbon fraction t/t ss (according to the approximation suggested by IPCC, it is 0.47 of ss);
- **3.67** is the conversion value from Carbon to CO2 (i.e., the ratio of Carbon moles to the sum of Carbon and Oxygen moles)

3.2 METHODOLOGY 2 - CARBON ACCOUNTING TOOL

The second tool used to calculate CO_{2eq} was the Carbon Accounting Tool developed in WP C4 of this project. This tool allows, through the input of forest data from field surveys, to quantify emissions, storage, and carbon substitution effects. With regard to emissions, losses related to forest use and fires are taken into account; epigeal biomass (*aboveground biomass), belowground biomass (belowground biomass*), soil organic matter (*soil organic matter*) and *dead organic* matter

[4] NFAP - Italian National Forestry Accounting Plan prepared by Institute for Environmental Protection and Research (ISPRA) with the contribution of Ministry of Agricultural, Forestry and Tourism Policies

(*dead organic matter*) are considered in counting stocks. Substitution effects, on the other hand, are counted by considering wood products from removals used for lumber and valuable timber and waste used in energy production.

The data entered are the same for each forest category present in the study area: the area covered by the stand, the growing stock (mc/ha) i.e., the epigeal volume, the current volume increment per year, the recovery i.e., the estimated biomass removed per year (mc/y), the area covered by fires (ha/y), and finally the percentage of assortments used for energy production. In order to be able to apply the carbon tool to the interventions carried out and note the differences in terms of Tons of CO_2 equivalent, calculations were carried out by considering an entire forest included of 500 hectares (average size of a forest included within the PFA) and assuming within it an annual cut of the value of the cuts actually carried out, thus assessing the differences between an ordinary cut and a more conservative cut.

The tool returns the total removal, removal with replacement and emission data in tons of CO_2 equivalent and the annual carbon balance considering also the emissions from purely energy use of wood.

More details on the use of the carbon accounting tool can be found in DL. C4.1 developed in this project.

The following is an example of data input for calculating the total carbon stock on the Pagno intervention.

Foglio di calcolo per bilancio speditivo del carbonio			
Compililare le celle colorate di arancione			
Dati Generali			
Area coperta da foreste	*500*	ha	
Volume ad ettaro	*353,76*	mc/ha	
Incremento corrente	*8,3*	mc/ha/y	
Area percorsa da incendi	*0*	ha/anno	
Utilizzazioni annue	*1098*	mc	
Assortimenti per produzione energia	*100,00%*	%	
Fattori di calcolo	**Valore**	**Fonte**	
Biomass Expansion Factor (medio)	1,39	*National Forestry Accounting Plan for Italy - 2019*	
Wood Basic Density (medio)	0,54	*National Forestry Accounting Plan for Italy - 2019*	
Rapporto medio Root/shoot	0,26	*National Forestry Accounting Plan for Italy - 2019*	
Coeff. Trasformazione biomassa secca	0,50	*Carbomark 2011*	
Coeff. Trasformazione C eq.	3,67	*Carbomark 2011*	
Rapporto medio SOM su stock biomas:	94%	*Presentazione Vitullo*	
Rapporto medio DOM su stock biomas	19%	*Presentazione Vitullo*	
Coeff. Sostituzione legno opera	2,10	*Sathre and O'Connor 2010*	
Coeff. Sostituzione legno energia	0,54	*Sathre and O'Connor 2010*	

Table 5:Example of data entered into the carbon accounting tool.

3.3 RESULTS

3.3.1 RESULTS METHODOLOGY 1

Below are the counts for the two interventions performed, calculated according to methodology 1.

1) FOREST PLOT "A" - PAGNO

Species	Intervention area	Total volume	Ordinary removable volume	Quantity removed from weighing	Volume removed	Volume saved compared to ordinary	CO_2 saved good practice
	has	m^3	m^3	q	m^3	m^2	T_{eq}
Chestnut tree	5,15	2.195	1.098	4.250	489	609	719

Table 6: Data of CO2eq saved by means of silvicultural management oriented toward less harvesting.

2) FOREST APPEARANCE "B" - Barge

Species	Intervention area	Total volume	Ordinary removable volume	Quantity removed from weighing	Volume removed	Volume saved compared to ordinary	CO_2 saved good practice
	has	m^3	m^3	q	m^3	m^2	T_{eq}
Chestnut tree	4,80	1.698	849	4.554	523	326	549

Table 7: Data of CO2eq saved through silvicultural management oriented toward less harvesting.

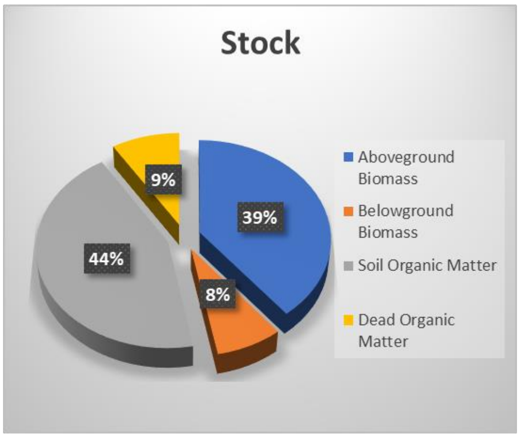
In total, due to the utilization system employed, emissions of 719 t CO equivalent were avoided$_2$ for plot "A" Pagno and 549 for plot "B" Barge for a total of about **1,268 t CO equivalent$_2$** . This result stems from lower withdrawals due to more conservative forest management than ordinary but goes equally to positive impacts on the conservation and enhancement of specific biodiversity, soil and water protection, and especially on the enjoyment of the intervention area.

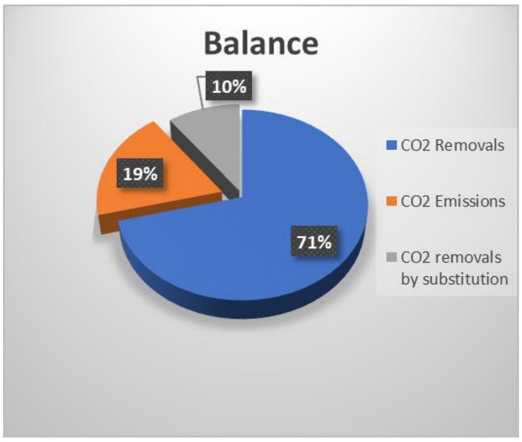
3.3.2 RESULTS METHODOLOGY 2

Below, the counts for the two performed interventions, calculated according to methodology 2, are shown. The results allow comparison of the accumulation of CO_2 maintained in the forest due to less biomass removal.

1) FOREST PLOT "A" - PAGNO

   a. Ordinary Intervention (Withdrawal 50%)

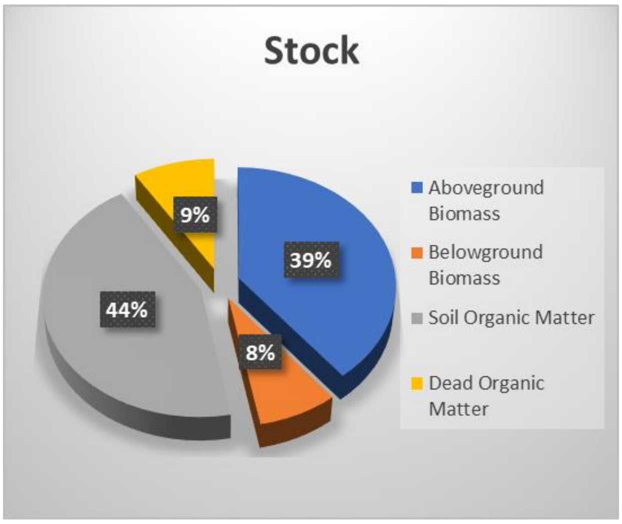


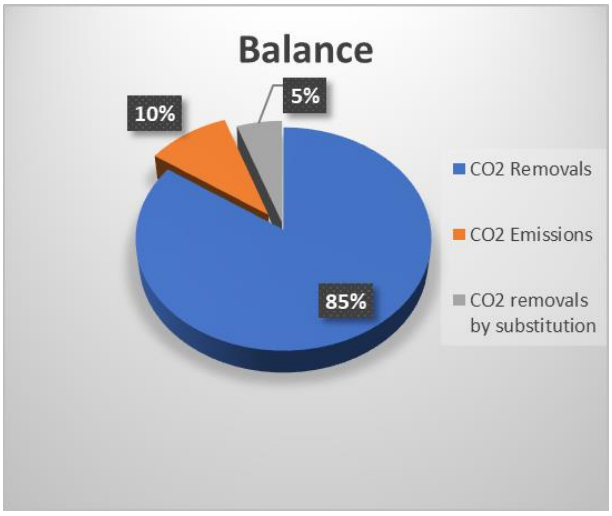


RESUME
Totale stock (t CO2eq)
588511
CO2 Removals
5711
CO2 Emissions
1511
CO2 removals by substitution
816
Yearly Carbon Balance
5016

Figure 2: Carbon stock and annual carbon budget graphs in the Pagno Intervention with ordinary drawdown.

   b. Intervention carried out (Withdrawal 27.6% of the commission)





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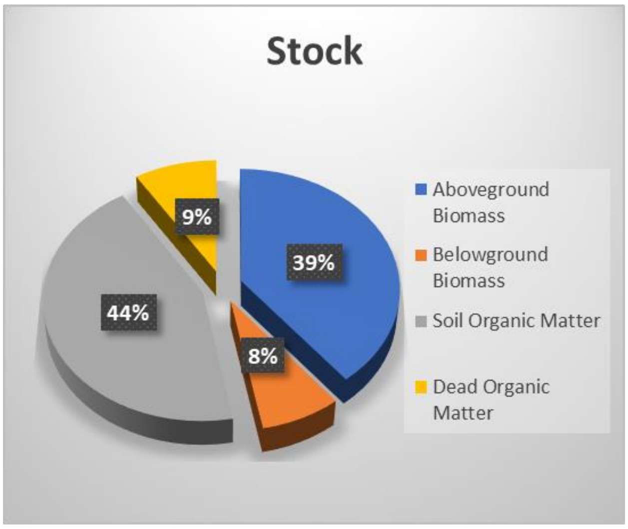
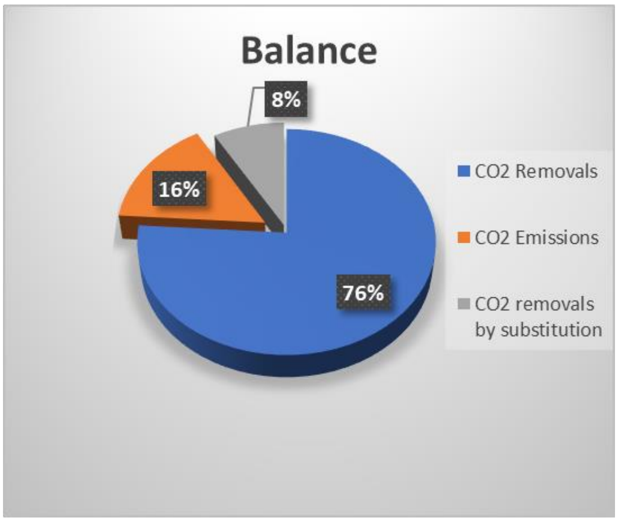
RESUME
Totale stock (t CO2eq)
588511
CO2 Removals
5711
CO2 Emissions
673
CO2 removals by substitution
363
Yearly Carbon Balance
5401

Figure 3: Carbon stock and annual carbon budget graphs in the Pagno Intervention with Climate smart drawdown.

2) FOREST APPEARANCE "B - Barge"

a. Ordinary intervention (Withdrawal 50% of the commission)

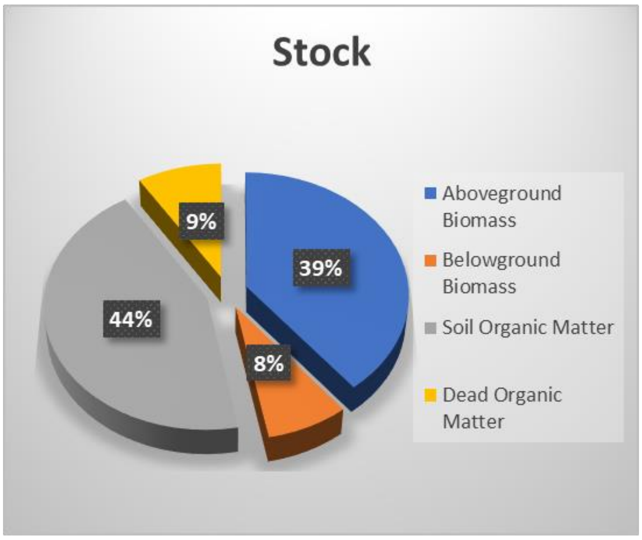


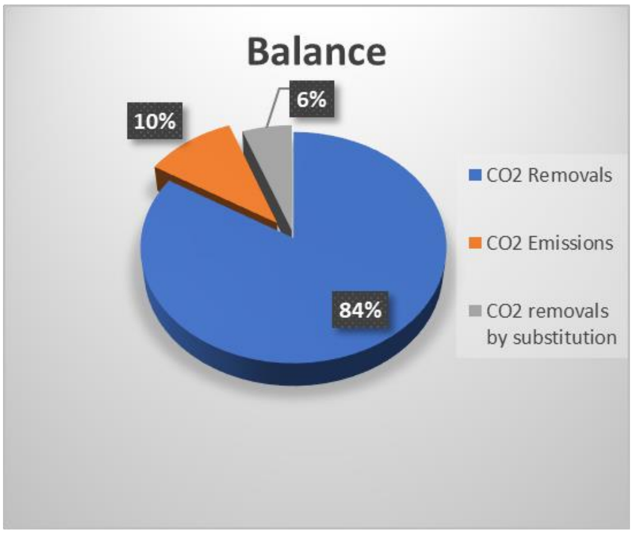


RESUME
Totale stock (t CO2eq)
537546
CO2 Removals
5711
CO2 Emissions
1168
CO2 removals by substitution
631
Yearly Carbon Balance
5173

Figure 4: Carbon stock and annual carbon budget graphs in the Barge Intervention with ordinary drawdown.

b. Intervention carried out (Withdrawal 30.8% of the commission)





RESUME
Totale stock (t CO2eq)
537546
CO2 Removals
5711
CO2 Emissions
720
CO2 removals by substitution
389
Yearly Carbon Balance
5380

Figure 5: Carbon stock and annual carbon budget graphs in the Barge Intervention with Climate smart drawdown.

As can be seen from the above graphs, by carrying out climate smart forest management, it is possible to have emission savings of tons of CO_2 . Specifically, using this calculation methodology, about 385 t were saved for the "A-Pagno" intervention and 207 t for the "B-Barge" intervention for a total of 592 t.

As can be seen, the two methods differ in their results. Specifically, with methodology 1 a total of 1,268 tons of CO_2 equivalent are calculated while with the methodology a total of 592 tons of CO_2 equivalent are calculated. This is related to the fact that the carbon tool also takes into account the tons of CO_2 emitted due to the use of wood as an energy source (in our case not accounted for its substitution effect). In addition, methodology 2 was not specifically designed for such counts but to calculate stocks of tons of CO_2 over a large area.

4 ECONOMIC FRAMEWORK OF INTERVENTIONS

The economic frameworks of the interventions carried out are given below:

4.1 FOREST PLOT "A" - PAGNO

The cost calculation is related to the actual expenses incurred in carrying out the intervention. Timber revenues are related to auction sale with an average price about 4.33 €/qle.

As shown in the economic statement below, the total cost of the intervention net of the sale of the extracted timber is **€82,014.08.**

ECONOMIC FRAMEWORK			
(A)	**Total amount of work to be tendered**		**€ 69.921,54**
	Of which:		
	Amount of work		*€ 69.100,02*
	Security charges		*€ 821,52*
Amounts available			
(B)	**V.A.T. on the works**	*(22% of A)*	**€ 15.382,74**
(C1)	*Technical expenses*	*(10% of A)*	*€ 6.992,15*
(C2)	*EPAP*	*(2% of C1)*	*€ 139,84*
(C3)	*V.A.T. on technical expenses*	*(22% of C1+C2)*	*€ 1.569,04*
(C)	**Total technical expenses**	*(C1 + C2 + C3)*	**€ 8.701,03**
(D)	**R.P. Compensation.**	*(2% of A)*	**€ 1.398,43**
(E)	***Total amounts available***	(B + C)	***€ 24.083,77***
(F)	**TOTAL COSTS.**	(A + E)	**€ 95.403,74**
(G)	**COST INCURRED BY UMCM WITHIN THE LIFE PROJECT**	(A+B+D)	**€ 86.702,71**
(H)	**COST INCURRED BY WALDEN WITHIN THE LIFE PROJECT AS PERSONNEL COST**	(C)	**€ 8.701,03**
(I)	**EXBUSCATED WOOD VALUE**		**€ 15.691,16**
	Of which:		
(I1)	*Assortments sold in truck yard*		*€ 13.389,66*
(I2)	*Assortments issued in temporary pitches for the property (estimated)*		*€ 2.301,50*
(L)	**TOTAL COST OF INTERVENTION (net of income)**	(F - I2)	**€ 82.014,08**

4.2 FORESALE PLOT B - "BARGE"

Cost estimates were based on the actual costs incurred in carrying out the intervention. The exbuscated timber was not sold but was allocated to the company performing the intervention.

ECONOMIC FRAMEWORK			
(A)	**Total amount of work to be tendered**		**€ 52.007,12**
	Of which:		
	Amount of work		*€ 51.188,64*
	Security charges		*€ 818,48*
	Amounts available		
(B)	**V.A.T. on the works**	*(22% of A)*	**€ 11.441,57**
(C1)	*Technical expenses*	*(10% of A)*	*€ 5.200,71*
(C2)	*EPAP*	*(2% of C1)*	*€ 208,03*
(C3)	*V.A.T. on technical expenses*	*(22% of C1+C2)*	*€ 1.189,92*
(C)	**Total technical expenses**	*(C1 + C2 + C3)*	**€ 6.598,66**
(D)	**R.P. Compensation.**	*(2% of A)*	**€ 1.040,14**
(E)	***Total amounts available***	(B + C +D)	***€ 19.080,37***
(F)	**TOTAL COSTS.**	(A + E)	**€ 71.087,49**
(G)	**COST INCURRED BY UMCM WITHIN THE LIFE PROJECT**	(A+B+D)	**€ 64.488,83**
(H)	**COST INCURRED BY WALDEN WITHIN THE LIFE PROJECT AS PERSONNEL COST**	**(C)**	**€ 6.598,66**

4.2.1 ACCOUNTING OF CO_2 STORED

As previously seen, the two silvicultural interventions performed resulted in savings (using methodology No. 1) of 1,268.00 tons CO_2 eq. This value, without the support of a third-party certification, cannot be validated for marketing in the offset market. By way of example, we go below to calculate the possible selling price at the time when such ton CO_2 eq were certified.

Intervention	Cost of intervention	Tons of CO equivalent₂ produced	Cost ton eq CO_2 (€/ton)
A- Pagno	€ 82.014,08	719	114,07
B- Barge	€ 71.087,49	549	129,49

Table 8: Calculation of cost per ton of CO2 saved related to the two pilot interventions.

As a yardstick, it is pointed out that the average price of offsets in Italy in the voluntary market is about €20/ ton CO_2 eq. This difference from the average price is related to the fact that the offsets to which the average value refers are derived from different sources and origins. In this case, on the other hand, the interventions carried out also affect other ecosystem services in addition to the storage of CO_2 such as, for example, the protection of biodiversity and the tourist enjoyment of the area; therefore, they have an added value that increases their selling price.

5 MONITORING PLAN AND FUTURE INTERVENTIONS

In order to monitor the carbon increase over time due to plant growth, a monitoring plan is planned to be carried out over time. Therefore, it is planned to set up 2 assay areas with a circular width of 15m. Within these areas a total trestling of the plants is to be carried out and 2 plants for each age class are to be cored. This will allow the growth rings to be counted and thus assess increments. A height measurement should also be provided for each plant cored. During the surveys, special attention should be paid to forest disturbances. If present, plants will have to be accounted for as total carbon loss present in the area. This type of monitoring will have to be done every 5 years for at least two cycles.

Future interventions aimed at maintaining the areas and achieving the set goals are also planned. In particular, a second intervention is planned for forest plot "A - Pagno" in about 15 years. In this intervention, residual stumps will be enfranchised by releasing 1-2 suckers and mature suckers already enfranchised in the first intervention will be harvested; a part of the harvest may also be the candidate individuals of the forest stand at maturity. The second intervention will then aim to continue/complete the forest establishment of the stand, further improving its dendrometric characteristics through the application of tree silviculture criteria.

For the forest plot "B - Barge", in order to contain the development of bramble and bracken, which are already highly developed over much of the stand area and young locust tree suckers, an intervention of containment and management of the herbaceous/arbustive component in the areas of greatest fruiting interest is envisaged. Among the implementable interventions, periodic sheep/goat grazing of the area is conceivable. In the case of grazing, this may be allowed on the areas specifically identified in the PFAs or farm pastoral plans approved by the regional structure responsible for forestry. The shrub containment action just described is to be implemented for a period of at least 5 years after the silvicultural intervention. After this intervention, monitoring of the combined effects of silvicultural cutting and shrub species containment will need to be carried out in order to identify possible management changes.

6 CONCLUSIONS

6.1 CRITICALITY

Although the interventions were successful and executed according to the design criteria, there were some critical issues in accounting for carbon offsets, mainly related to the guidelines issued by Piedmont Region. Specifically, the guidelines provide for the possibility of generating certified credits and consequently selling them if the intervention performed has as an amount of timber harvested between good practice and ordinary. In the case of forest plot "A - Pagno," the drawdown had to be between 35 percent (good practice) and 55 percent (ordinary drawdown). In our case the drawdown was 27.7%. This was influenced by the large amount of standing and dead dry timber on the ground whose removal was required by the construction management. Such timber had not been considered in the forestry surveys for the design. In addition, the estimation of the extent of work with the company, i.e., construction management, was based primarily on canopy and not on mass: the large amount of standing dead trees thus affected the estimate of canopy and consequently the removal done by the company. Thus, although this result allowed for more carbon to be maintained in the forest, this cannot be certified for sale according to regional regulations. In order to carry out an intervention to generate saleable offsets, it will be necessary - in replication actions - to be more present at the execution of the work, in order to monitor the cuts and identify whether the company is cutting too much or too little by providing them with possible indications and expedients sa follow.

For forest plot "B - Barge," the main critical issues are related to the estimation method used in the initial project, which did not include the execution of the intervention by using the cable crane and therefore required changes during construction with respect to the quantities of timber exbursed.

An additional critical issue that emerged at both sites was the poor quality of the timber. Chestnut coppice that was aged and close to collapse, and had a lot of dry wood, crashed to the ground or standing dead; green timber, on the other hand, often had onion defects. These factors resulted in the exclusive use of exbuscated timber for energy production. This aspect can be analyzed from two different points of view with respect to the carbon cycle: on the one hand, this timber goes to make "substitution effect" for other fossil fuels for energy production; on the other hand, if this timber were used for nobler purposes, the carbon in it would be "immobilized" for much longer and would not be immediately emitted into the atmosphere due to combustion.

6.2 STRENGTHS

The methods used to account for forest carbon related to good silvicultural practice proved to be effective. The possibility of generating offsets due to the good practices implemented would allow for additional economic revenue from the forest and less environmental impact. In addition, additional ecosystem services could be generated and quantified through more sustainable management. By using the IBP method in both sites it has been possible to maintain and increase the level of biodiversity present, and with the removal of most of the dead wood the risk of fire has decreased. The latter eventuality, if it had occurred, would have released a large amount of particulate matter and CO_2 into the atmosphere thus going to increase greenhouse gas emissions into the atmosphere.

The restoration and maintenance of the road system has also allowed greater tourist enjoyment of the area and will allow further forest improvement. Especially in the forest plot "B - Barge," a cut was made to facilitate access to the "Ciabot," a rural building of particular historical-cultural interest. The transition, in both interventions, from coppice or mixed government to a high forest government allows to increase the resistance and resilience of the forested areas. This aspect, considering climate change and the increasingly frequent extreme phenomena related to it, makes forests less susceptible to future impacts and disturbances.