WP1 Shared modelling framework and learnings

D1.2 – Description of scientific methods

Task 1.2 Foreground LCI

Carbon Flux Model validation process

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PROJECTS DETAILS			
Project title		Aligning Life Cycle Assessment methods and bio-based sectors for improved environmental performance.	
Project acronym	ALIGNED	**Start / Duration**	01/10/2022 – 36 months
Type of Action	RIA	**Website**	www.alignedproject.eu

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1) Description

This document provides the records and explanation of the validation process of the Carbon Flux Model. It includes a description of the methods for validation, the justification of assumptions and data manipulation, the results yielded by the process, and some interpretation of these results. A detailed description of the model itself is provided in De Rosa et al. (De Rosa et al., 2017)

The validation is applied to the following version of the model available in the T1.2 repository:
ALIGNED-T1.2-LCA-Carbon-Flux-model.xlsx

The data for the validation process is available in the T1.2 repository: *ALIGNED-T1.2-Carbon-Flux-model-validation-data.xlsx*

2) Overview of the validation process

The goal of the validation is to assess the extent to which the ALIGNED Carbon Flux model can replicate carbon stock results of empirical studies from productive forests with different thinning practices. The validation process was carried out in the following steps:

1. Identifying literature containing data that is comparable to the output of the Carbon Flux model.
2. Modelling scenarios (species characteristics, forest management practices) from the identified literature in the Carbon Flux model, to reproduce results.
3. Comparing the data output from the modeling step to the original published data.

3) Literature chosen for validation

The validation was conducted against four peer-reviewed studies that included relevant, observation-based data points. The studies were identified based on relevance and data availability through a search for relevant key words ("forest management"; silviculture; thinning; "biomass accumulation"; "carbon stock") in the ScienceDirect and Google Scholar databases, and ResearchRabbit software. No systematic review was carried out.

Table 1 shows the studies used in the validation. All four studies include data about planted forest management experiments, with records of species, geography, final age of stand, thinning age(s), thinning density, biomass growth, and carbon stock in biomass. One study models a plantation similar to the default scenario in the Carbon Flux Model; three studies model plantations in Europe; and one study models a North American plantation.

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Table 1 Overview of the literature used to validate the ALIGNED model data

Authors	Year	Title	Reference
Bravo-Oviedo, A., Ruiz-Peinado, R., Modrego, P., Alonso, R., & Montero, G.	2015	Forest thinning impact on carbon stock and soil condition in Southern European populations of P. sylvestris L.	(Bravo-Oviedo et al., 2015)
Nilsen P, Strand L	2008	Thinning intensity effects on carbon and nitrogen stores and fluxes in a Norway spruce (Picea abies (L.) Karst.) stand after 33 years	(Nilsen & Strand, 2008)
Hoover C, Stout S	2007	The Carbon Consequences of Thinning Techniques: Stand Structure Makes a Difference	(Hoover & Stout, 2007)
Ruiz-Peinado, R., Bravo-Oviedo, A., Montero, G., & del Río, M.	2016	'Carbon stocks in a Scots pine afforestation under different thinning intensities management'	(Ruiz-Peinado et al., 2016)

4) Modeled scenarios

Since the studies validated against presented observed values, parameters such as *mean annual increment* (MAI), *biomass conversion and expansion factor* (BCEFs), *basic wood density* (WD), and *carbon factor* (CF) were not, or not always, specified. These parameters were adjusted in the Carbon Flux model to reproduce the results in the pre-treatment scenarios. *Table 2* shows the modeled scenarios after the following adjustments:

1. For WD and CF, if not specified by the study, values from the ALIGNED database were inserted.

2. For BCEFs, the mean value from the IPCC dataset relevant for the species and geography was used (e.g. Boreal conifer, >100 m3.

3. For MAI, the adjustment was made in a trial-by-error fashion, within the expected range of values for the parameter based on previously collected, species-specific data. For example, if the MAI was reported between 3,7 and 8,9, values between these numbers were inserted into the model until the produced results matched the study results.

4. The ALIGNED model specifies thinning intensity as a percentage of biomass to be removed, while the studies specify it as a percentage of basal area or relative density. This caused a significant overestimation of the removed volume in the model, skewing the final (post-treatment) results in all modeled scenarios in which thinning was carried out. To find an approximate ratio between the removed volume and the removed of basal area or density, another trial process was carried out. After the successful calibration of the control (no thinning) scenarios or the pre-treatment state, the reported thinning ratio was reduced until the results of the model matched the observed results from the studies. This process led to the assumed conversion ratio of 0.5 between the basal area or density removal and the volume removal.

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Table 2 An overview of the input parameters used in all modelled scenarios

Scenario	Species	Final age	$BCEF_s$	MAI	WD	CF	Thinning age 1	Thinning intensity 1	Thinning age 2	Thinning intensity 2	Thinning age 3	Thinning intensity 3	Thinning age 4	Thinning intensity 4	Publication
Bravo-Oviedo A	Pinus s.	90	0.55	5	0.42	0.46	-	-	-	-	-	-	-	-	(Bravo-Oviedo et al., 2015)
Bravo-Oviedo C	Pinus s.	90	0.55	5	0.42	0.46	50	7.5	55	7.5	65	7.5	75	7.5	(Bravo-Oviedo et al., 2015)
Bravo-Oviedo D	Pinus s.	90	0.55	5	0.42	0.46	50	16	55	16	65	16	75	16	(Bravo-Oviedo et al., 2015)
Ruiz-Peinado C	Pinus s.	52	0.55	10.2	0.42	0.51	-	-	-	-	-	-	-	-	(Ruiz-Peinado et al., 2016)
Ruiz-Peinado M	Pinus s.	52	0.55	10.2	0.42	0.51	22	5.5	32	9	42	15.5	-	-	(Ruiz-Peinado et al., 2016)
Ruiz-Peinado H	Pinus s.	52	0.55	10,2	0.42	0.51	22	7.3	32	10.3	42	14.7	-	-	(Ruiz-Peinado et al., 2016)
Hoover c	Acer spp.	77	0.8	3	0.56	0.49	-	-	-	-	-	-	-	-	(Hoover & Stout, 2007)
Hoover TfB	Acer spp.	77	0.8	3	0.56	0.49	53	17.5	67	17.5	-	-	-	-	(Hoover & Stout, 2007)
Nilsen 2070	Picea a.	55	0.53	5.5	0.37	0.49	22	17.5	-	-	-	-	-	-	(Nilsen & Strand, 2008)
Nilsen 1100	Picea a.	55	0.53	5.5	0.37	0.49	22	33	-	-	-	-	-	-	(Nilsen & Strand, 2008)
Nilsen 820	Picea a.	55	0.53	5.5	0.37	0.49	22	37	-	-	-	-	-	-	(Nilsen & Strand, 2008)

The observed datapoints were categorized into two groups: pre-treatment and post-treatment. Pre-treatment values refer to observations in undisturbed control plots, or observations made before thinning treatments. Post-treatment values refer to observations recorded at the end of the study period, after all thinning operation have been carried out.

Three of the four studies included data points for pre-treatment stands. These were used to calibrate the model. As Figure 1 shows, the model was able to generate values closely matching all the observed data points. In the case of the fourth study, the parameters' values were adjusted until they provided the closest match in results to the first scenario.

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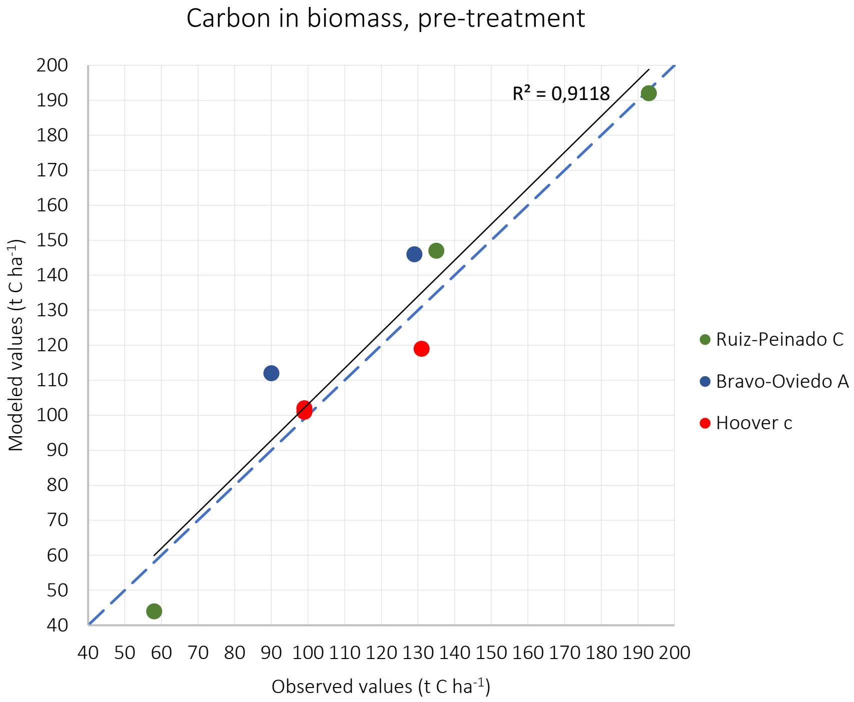

Figure 1 plots the observed pre-treatment values against the outputs of the model after fitting the parameters. The blue dashed line represents perfect (1:1) accuracy for visual comparison, while the black continuous line shows the linear trend between the two datasets.

5) Comparing the observed and modeled data

The scenarios including thinning practices then were replicated in the Carbon Flux model, with the model rotation time set equal to the final observation age in the studies. The modelled carbon stocks at the end of the rotations were compared to the corresponding observed values, as shown in *Figure 2*:

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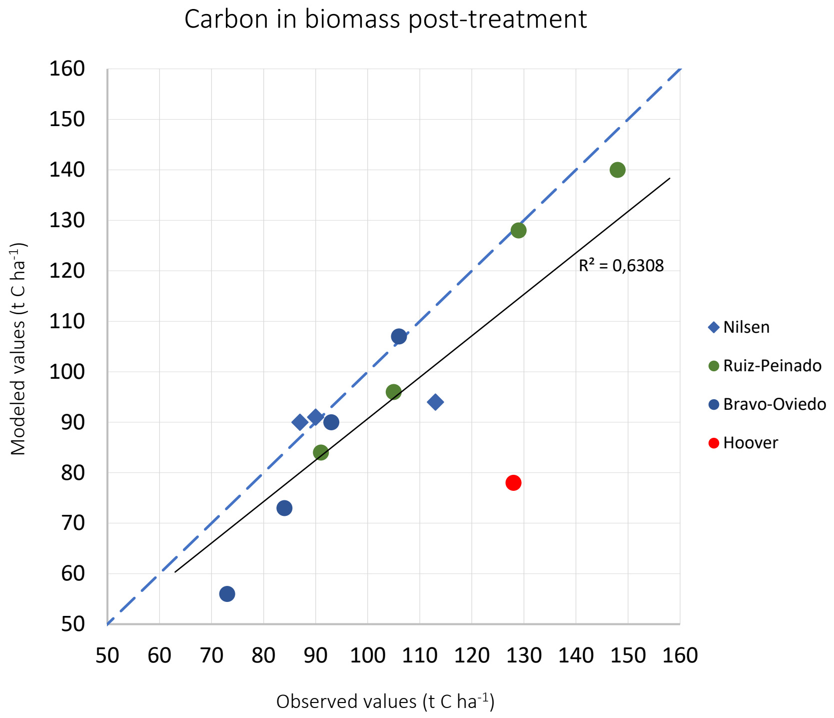

Figure 2 plots the observed carbon stock in biomass data against the outputs of the ALIGNED model at the end of the study period. The blue dashed line represents a perfect (1:1) accuracy for visual comparison, while the black continuous line shows the linear trend between the two datasets.

This limited data sample suggests that the Carbon Flux Model is able to replicate observed results of carbon stock in growing biomass after thinning operations with a reasonable accuracy. The validation furthermore suggests that:

- the modeled data tends to underestimate on-site biomass after thinning operations, and overestimate the volume of harvested biomass
- the model does not capture the changes in biomass growth rate in response to different thinning regiments, but reasonably replicates carbon stocks in the biomass by the end of the study period or rotation time
- when "thinning from below" is assumed, a factor of 0.5 applied to the basal area or plot density-based thinning intensity produces reasonably accurate results

It is important to note that a validation of the model for all possible scenarios is outside of the scope of this project. Based on the specific data sample described above, the authors believe it can be reasonably assumed that the Carbon Flux model produces valid outputs for the carbon dynamics of productive forests. Validating the results of specific scenarios against observed data is recommended, when possible.

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6) References

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