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CROSS Harmonization & HPC modelization of FOREST Datasets

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Table of Contents

1 INTRODUCTION AND PURPOSE 5

2 CAMBRIC (CALIDAD DE LA MADERA EN BOSQUES MIXTOS) 6

2.1 DESCRIPTION 6
2.1.1 Objectives 6
2.1.2 Pilot requirements 7
2.2 PREPARATION 8
2.2.1 Schedule 8
2.2.2 Pilot Development 9
2.2.3 Input data 12
2.2.4 Strategies used and problems faced 12
2.3 EXECUTION 13
2.3.1 Test execution 13
2.3.2 Results 13
2.3.3 Reported data: files, formats, etc. 13
2.3.4 Strategies used and problems faced 13

3 FRAME (FOREST FIRES ADVANCED MODELIZATION) 14

3.1 DESCRIPTION 14
3.1.1 Objectives 14
3.1.2 Pilot requirements 15
3.2 PREPARATION 21
3.2.1 Schedule 21
3.2.2 Pilot Development 22
3.2.3 Input data 24
3.2.4 Strategies used and problems faced 24
3.3 EXECUTION 25
3.3.1 Test execution 25
3.3.2 Results 26
3.3.3 Reported data: files, formats, etc. 27
3.3.4 Strategies used and problems faced 28

4 FINAL REMARKS 29

REFERENCE DOCUMENTS 30

DEFINITIONS, ACRONYMS AND ABBREVIATIONS 32

ANNEXES 33

ANNEX I CAMBRIC REQUIREMENTS, GENERAL TABLE 33
ANNEX II CAMBRIC EXTERNAL DATASETS, GENERAL TABLE 37
ANNEX III CAMBRIC DATA TRANSFORMATION, GENERAL TABLE 38
ANNEX IV FRAME REQUIREMENTS, GENERAL TABLE 39
ANNEX V FRAME EXTERNAL DATASETS, GENERAL TABLE 42
ANNEX VI FRAME DATA TRANSFORMATION, GENERAL TABLE 43

List of Figures

Figure 1 CAMBRIC pilot overall perspective 6
Figure 2 SIMANFOR simulator achitectura 9
Figure 3 Forest Explorer. Pinus sylvestris area selection 10
Figure 4 Wood end uses and sizes 11
Figure 5 Ibero model structure 12
Figure 6 FRAME general scheme 14
Figure 7 FRAME schedule up to M18 21
Figure 8 FRAME schedule from M18 to end 22
Figure 9 Example of ASCII file representing terrain from IGN 24
Figure 10 Log of simulation activity on Linux server, success status 26
Figure 11 Output matrix of cells, status over time 27
Figure 12 Ad-hoc interface for testing evolution of fire 28

List of Tables

Table 1 CAMBRIC activities. 8
Table 2 FRAME external datasets. 19
Table 3 FRAME data transformation considered. 20

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Reviewer(s):	Alexandra Fonseca (DGT) Ana Luisa Gomes (DGT) Rafael Silva (DGT) Jesús Lorenzana (SCAYLE) Álvaro Fanego (SCAYLE) Guillermo Vega (UVa) Belén Fierro (TRAGSATEC) Daniel Molina (TRAGSA)

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1 Introduction and purpose

This deliverable describes the works performed during the first 18 months of Cross-Forest Project regarding the development of the pilots CAMBRIC and FRAME, and shows the status of both pilots. The document contains a description of activities and tasks executed from the beginning of the Project up to 28/02/2020, the preparation and performance of tests (running on local and on HPC environment), as well as explanations of the problems faced and the ways that have been found more suitable to solve them.

During the first months of the Project, a strong multidisciplinary effort has been necessary to establish a good definition of requirements. Both FRAME and CAMBRIC teams and the rest of partners have worked in collaboration (through meetings and audio-meetings) to establish a homogeneous definition of requirements, which is understandable for everyone, and allows including all necessary information to face the different activities within the project. The pilot requirements represent a “common ground” from where the different activities in the Project can get the required information. They will be described in coming sections of this document, and will be included in a revised version of “D 3.1 User specifications and Requirements”.

For the sake of clarity, the structure of the document is organized in two main sections, focused on both pilots CAMBRIC (2) and FRAME (3). For each pilot:

(i) a general “Description” is included containing the objectives and requirements

(ii) the “Preparation” section describes the planning of the tasks, the work performed up to 28/02/2020 for the first trial, input data used by the simulators, faced problems and decisions/strategies adopted to solve them

(iii) the “Execution” section describes the first tests performed for each pilot on local / HPC environment, and explanation on the results obtained/expected, faced problems and decisions/strategies adopted to solve them, as well as some indications for future iterations.

A common section (4) containing some “Final remarks” is included at the end of the deliverable.

The preliminary results and tentative conclusions derived from this first trial are included in “Deliverable 4.3 Evaluation of results - Interim Report”, as stated in the project planning.

2 CAMBRIC (CAlidad de la Madera en Bosques mIxtos)

2.1 Description

Pilot CAMBRIC intends to take advantage of both HPC computing and Linked Open Data technology to calculate wood stocks and simulate future status..

Technical and data requirements have been defined, as well as the necessity of a new simulator version. The first area in which we will test the process is High Ebro Valley, a well-known area with Scots pine forests.

In this section, we display what we have done in this iteration and what we pretend to perform until the end of the project

2.1.1 Objectives

The aim of CAMBRIC is to forecast wood quality in mixed forest at big surface levels (over municipality). Using Big Data as source information provided by Spanish National Forest Inventory, and Spanish National Forest Map, and eventually data from Remote Satellite Sensors or LiDAR, a set of Yield Models adequate for each species composition and region, and different management scenarios, we will develop a dynamic information platform with wood yield as raw material for each different lumber industry.

There will be five silvicultural scenarios as proposed by Duncker et Al. (2012): (1) Passive: Unmanaged forest nature reserve; (2) Low: Close-to nature forestry, (3) Medium: Combined objective forestry, (4) High: Intensive even-aged forestry and (5) Intensive: Short-rotation forestry.

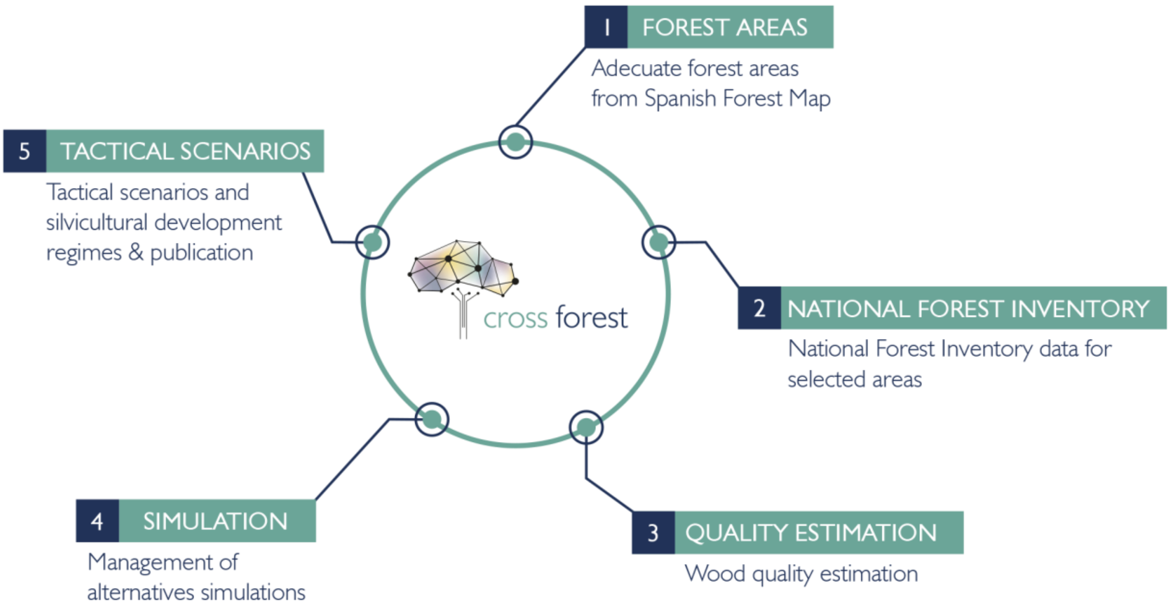

Figure 1 CAMBRIC pilot overall perspective

These management schemes will be simulated across a gradient of forest mixtures (Pretzsch & Schütze, 2014 and Heym et Al. 2017) (from pure to multi-species stands) for the target species. Simulations will allow to classify timber products on a log size and stem knot-free length basis. The work-flow (see

Figure 1) will be (i) select adequate areas with the information provided by the Spanish Forest Map covers, (ii) extract forest inventory data for the selected areas, (iii) estimate wood quality by applying stem taper equations (Rodríguez et Al. 2017) to inventory data, (iv) simulate different silvicultural alternative for the Spanish NFI data to explore the impact of species mixture on wood quality and (v) develop tactical scenarios for the different silvicultural regimes and publish output data following the Linked and Open data approach defined in the project.

The following taxa will be selected as model species to analyse the availability of wood and its quality for different end uses: *Pinus sylvestris*, *Pinus pinaster, Pinus nigra*, *Fagus sylvatica, Quercus pyrenaica, Quercus robur* and *Quecus petraea*, both pure and mixed stands of these species will be analysed.

In this first iteration, as a test to prove functioning at HPC, a small subset of the NFI will be sliced, comprising pure *Pinus sylvestris* stands, and a restricted area well known for this species, the High Ebro Valley at the north of Burgos province. Provided intensive scenarios are not suitable to this species, we will only test the first four scenarios.

2.1.2 Pilot requirements

CAMBRIC pilot aims to estimate wood quality in current and future situations. For achieve this goal it is necessary to perform simulations, and we have defined what requirements are needed to fulfil this task. Therefore a new version of the simulator is also required, as well as the inclusion of needed variables in the ontology of the project.

These pilot requirements are categorized in:

- CAMBRIC – Input Data Definition. Basic variables representing both, forest stands and trees inside are described.
- CAMBRIC – Models Definition. Mathematical models aiming to represent how trees and stands evolves are defined, based on the structure of *IBERO model* (Lizarralde et Al. 2010a and 2010b).
- CAMBRIC – Industry Requirements. Raw material characteristics for each end use are define, as well as the way to estimate the quantity available by year and area.
- CAMBRIC – Simulation Definition. Given a stand and trees characteristics at a year and age, a simulation shows how change and what silvicultural treatments are applied during a period of time. The five different silvicultural scenarios proposed by Duncker et Al. (2012) should be defined, adapted to each species or species composition characteristics and possible end use.
- CAMBRIC – Data preparation. Based on the National Forest Map, strata for each species or species combination will be prepared. Input data for simulations will be the National Forest Inventory data associated to each patch.
- CAMBRIC – Simulation. For each patch and strata all suitable simulations will be performed, aiming to obtain a detailed map of wood availability by industry and year (or period of time)

The general tables that contain the actual state of requirements for the first iteration, as well as data requirements and data transformations, can be found in annexes I to III.

2.2 Preparation

2.2.1 Schedule

The activities developed under the framework of the Pilot project CAMBRIC are summarized in the following table with temporal specification

Table 1 CAMBRIC activities.

	Months																	
Activities and tasks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Simanfor simulator characteristics checking						X	X	X										
New simulator redefinition							X	X	X									
New simulator programming									X	X	X	X	X	X	X	X	X	
New simulator test																		X
New simulator test in HPC																		
Species codification and link to different IRI and URL											X	X	X	X	X			
requirements definition													X	X	X	X	X	X
Help to Uva-GSIC in IFN and MFE Ontology definition								X	X	X			X	X	X			X
Species area selection																X	X	X
End use size and quality definition																X	X	X
Scenarios definition																		X
Growth and yield models codification															X	X	X	X
Models fitting for non available species (next iteration)																		
Simulation development and output analysis																		X
	2018				2019												2020	
	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2

After the first iteration, the schedule will follow the next steps:

- New simulator texting in PC, both in Linux and in Windows, will be run until mid March.
- After a verification of the final version, tests in HPC will be run until the end of March.
- Scenarios definition, will be set up until the end of May.
- New growth and yield models, will be adjusted until the end of May.
- End use and quality definition, will be run until the end of May.
- Species area selection, will be run until the end of July.
- Growth and yield models codification will be done until the end of November.
- Simulations, will be run until the end of the project.

2.2.2 Pilot Development

Overview

Pilot CAMBRIC is aimed to show a map of quality and quantity of wood in current state and the evolution among next decades, for the Spanish territory. Two main tasks are required, calculate stocks and simulate its evolution. Herein below we will describe steps accomplished to yield a simulator able to perform this task as well as handle and transform required databases.

New simulator redefinition. As a preliminary requirement, we need a simulator able to run in HPC Calendula. We already have a web-based simulator, SIMANFOR, able to run several types of models, but it is based on .NET and C# technology, so it is very complicated to adapt the technology to Calendula. After a meeting with HPC team held on 2nd February 2019, we decided to completely reprogram SIMANFOR, what supposed a non-expected challenge for the pilot project, and implied the necessity of collaboration with the enterprise that developed previous version of SIMANFOR, sngular.

Simulator suitability to be used in CALENDULA HPC has been the main problem faced, and the decision of completely reprogramming SIMANFOR implies some delays in the original schedule, but it will allow us to gain in versatility and efficiency.

Based on the main idea of SIMANFOR, able to handle new growth models independently of the core and with a simple coding of the equations, new Linux compatible technology will replace previous one.

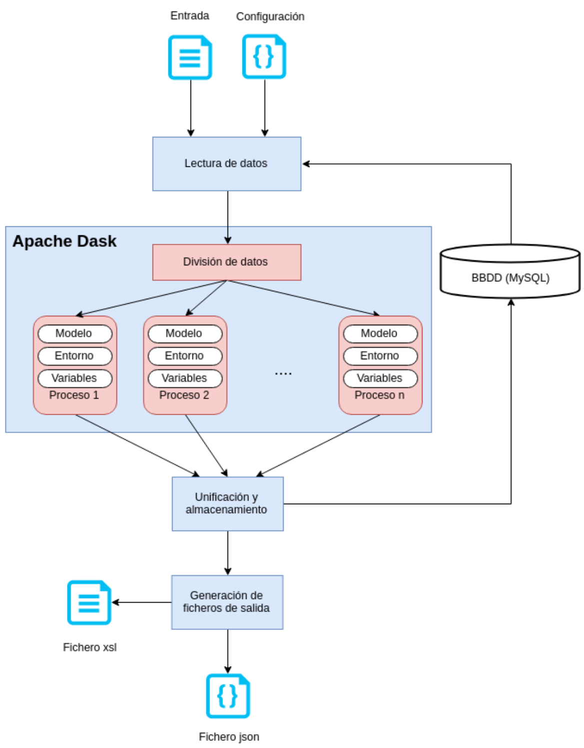

Figure 2 SIMANFOR simulator achitectura

SIMANFOR will be a core of simulation, but able to be deployed in three different environments, i) desktop PC, ii) cloud with the ability of run in different nodes, and iii) HPC, similar to cloud but compatible with MPI and OpenMP comunication. Technology will be typed Python 3.6 within Dask (Dask Development Team 2016) to support MPI programming (The Open MPI Project ©2004-2020 and Dask Development Team 2016).

The structure of the simulator is represented in figure 2, where based in input data and scenario, SIMANFOR core is able to perform the simulations and return a set of outputs, one for each scenario node. Input and output data will have the same structure aiming to use output as input in another simulation. Data format will be flexible, allowing the use of centralized SQL database, LOD database or single csv/xls files. Scenario input will be JSON format, allowing easy human and machine readability.

New simulator programming. Although this task is being perform by sngular, a regular interaction and monitoring of the progress has been carried out.

New simulator test. Tests on new simulator version are being carried out on February and March.

New simulator test in HPC. Provided previous tests perform well, new simulator version will be test on HPC on March.

Species codification and link to different IRI and URL. The complete list of tree species, genus and families coded in National Forest Inventory database has been paired with the following recognized sources of data: Scientific name, recognised sinonime, IRI assigned in CrossNature project, URL in Wikipedia, IRI in Dbpedia, IRI in NCBI (National Center for Biotechnology Information https://bioportal.bioontology.org/ontologies/), IRI in Wikidata, URL in The plant list database (Royal Botanic Gardens, Kew https://www.kew.org/) and IRI in Wikispecies. This issue will allow federated queries based on specific name of tree species.

Requirements definition. Prior to any other activity, requirements described in section 2.1.2 should be clearly defined and agreed with project partners. Database formats and contents, scenario definition, models structure and outputs formats are keystone of the pilot and required a very long time.

Help to UVa-GSIC in IFN and MFE Ontology definition. Based on data requirements of the pilot, we helped Uva-GSIC team to disentangling these two important sources of data.

Species area selection. Provided MFE ontology has been already developed, it will be used to characterize suitable areas for each taxa, and differencing levels of development. Simulations will be performed for each group, using associated IFN plots to perform the simulations. Figure 3 shows how Forest Explorer allows selection of Forest Map and included National Forest Inventory plots in an specific area.

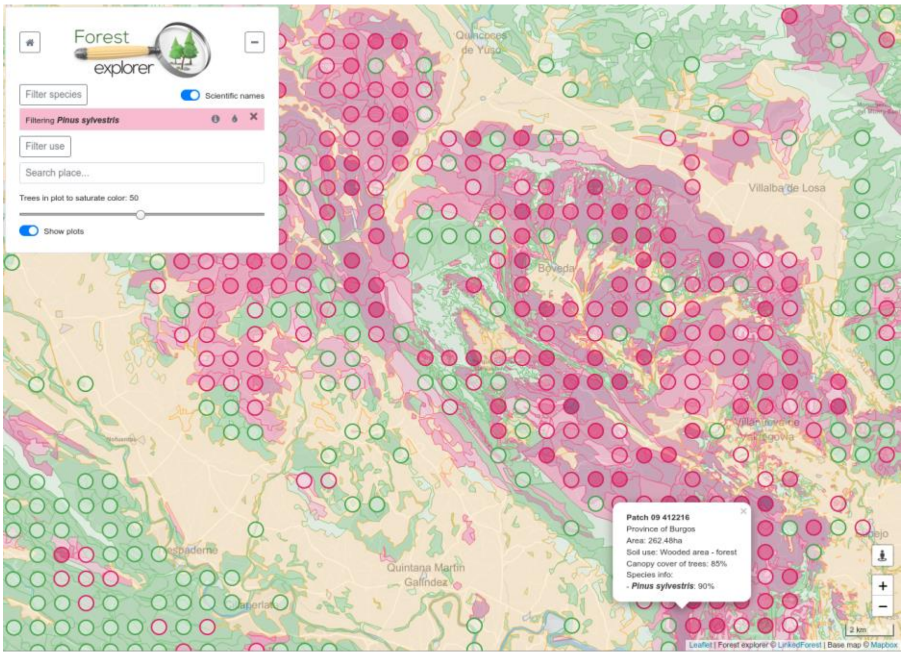

Figure 3 Forest Explorer. Pinus sylvestris area selection

End use sizes and quality definition. Wood, as raw material can be used in different primary industries. The suitability of wood depends on log size, both maximum and minimum diameter and length are crucial. Species is also very important as well as the amount of logs in a close area.

Attending these requirements we will calculate the amount of wood in each patch of the MFE for these end uses ordered in descending prize (Figure 4): Veneer (D > 40 / 20 L > 2,6 3), Wood for saw big (D > 40 L > 2 + 2), Wood for saw small (D > 25 L > 2,5), Wood for saw canter (D < 30 L > 2), Wooden post (D 20 - 30 L 6,25 – 14), Wood stake (D < 15 L > 1,8), Chips (any size)

Simulator output can be tuned to represent the amount of wood available for each industry and year within an specific area. These outputs will be stored in the project database in LOD format, easily browsable by the sector stakeholders.

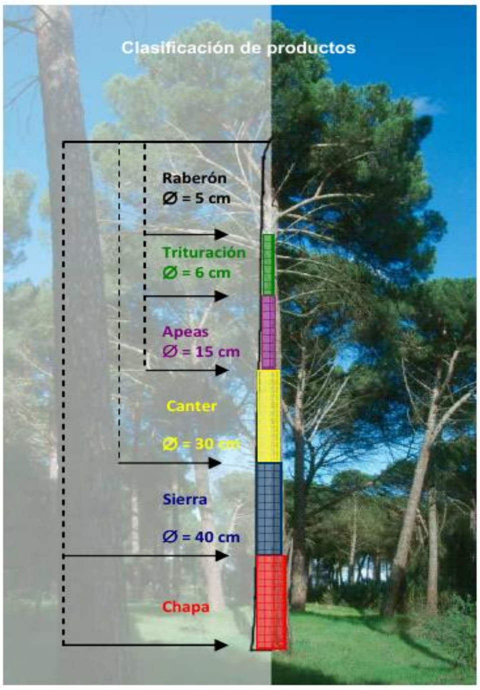

Figure 4 Wood end uses and sizes

Scenarios definition. A very important issue concerning our simulations is the definition of the stand evolution and the different interventions will be performed. Each scenario will be stored as JSON file, and stored in the project database.

Growth and yield models codification. Models are constitutive key of the simulations, which allow simulator perform changes that occur in each lapse of time. These changes are in size, diameter and height, or in health status. The model should be able to predict mortality or ingrowth of trees. A suitable model should include the following equations: Stand Quality Curves, Diameter and height growth, Mortality, Ingrowth and Taper equations.

Ibero models (Figure 5) have been developed for *Pinus pinaster* and for *P. sylvestris* and programmed for previous version of SIMANFOR, and now transcribed to new SIMANFOR in Python.

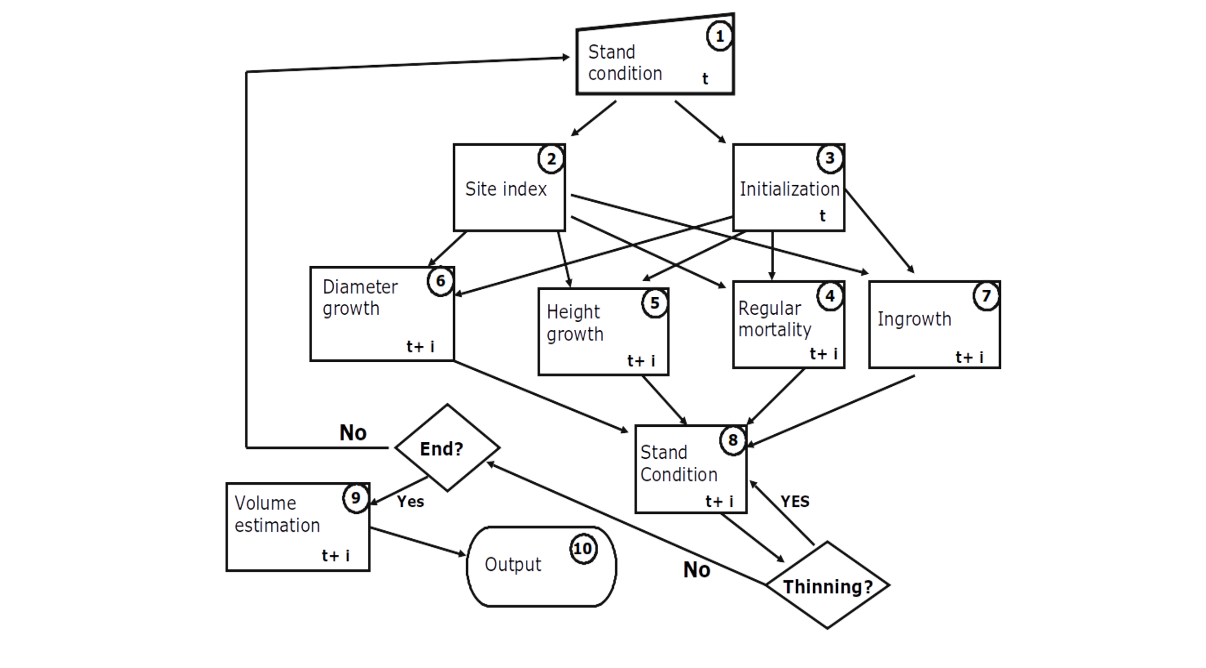

Figure 5 Ibero model structure

Models fitting for non available species. After including the code for all species already found in literature, in the next iteration equations for the rest of the species and mixture of species should be fitted.

Simulation development and output analysis. In this first iteration, as soon as we have a reasonable good version of SIMANFOR we will start testing the well known area of High Ebro Valley, mainly populated with *Pinus sylvestris* and for which stand characteristics are already studied in our group.

The different patches containing subject species has been selected and the NFI plots paired with the associated strata.

2.2.3 Input data

Input data is key information. As detailed in the requirements (annex I), tree size variables and stand characteristics should be provided to perform simulations.

SIMANFOR simulator is able to handle different input formats like CSV, EXCEL or JSON, what is defined in simulation input file. Outputs formats can be the same type as input, and are compatible, so an output can be used as input in a different simulation.

The nominated area for first test is High Ebro Valley, a well known area of Scotch pine.

2.2.4 Strategies used and problems faced

Simulator suitability to be used in CALENDULA HPC has been the main problem faced, and the decision of completely reprogramming SIMANFOR implies same delays in the original schedule, but it will allow us to gain in versatility and efficiency.

2.3 Execution

2.3.1 Test execution

SIMANFOR simulator core will be able to run in PC, cloud or HPC environments. Provided actual state of software is “alpha” we did not have time to run any simulation an can only indicate how it will be. We aim to compare scenario outputs from previous and new version, and fit bugs before doing any other test. These verifications and simulator code refining is currently running and will be run until mid March.

Testing in CALENDULA HPC will be run as soon as possible, intended for early March.

Simulations will be run in all possible environments, HPC, PC and cloud (old version), just to be sure everything performs OK in CALENDULA.

Next iteration will consist on running simulations over the rest of the area of Scotch pine, and other species for which growth and yield models are available. Last iteration will include simulations among the rest of taxa selected in the pilot.

2.3.2 Results

Provisional results of simulations are promising, and format will be compatible with our old simulator ones as well as with free or LOD formats. The ability to generate outputs in JSON format let automatic publication in project database.

2.3.3 Reported data: files, formats, etc.

For evaluation purposes a non-real test will be set up, based on a specific real-based ramdomly generated set of one hundred plots with one hundred trees per plot. This kind of data provide a balanced source of data, without null data or any other kind of data that can disturb results.

The scenario proposed for wood production will be used to evaluate this plots, in which trees will evolve from 20 to 150 years with 6 thinnings at 20, 30, 40, 50, 65 and 80 years age.

Performance measured in computing time will compare different versions of SIMANFOR: current online version, linux-PC, windows-PC and HPC (without parallelization).

New SIMANFOR will be able to provide more tailored outputs, but for comparing purposes only total commercial volume will be analysed.

2.3.4 Strategies used and problems faced

Main problem in development of the pilot was the complexity of prior SIMANFOR version and subsequent delay in having initial versions of CAMBRIC to test.

We have been focusing on data preparation, scenario and output definition and models programming.

3 FRAME (Forest fiRes Advanced ModElization)

3.1 Description

FRAME intends to take advantage of both HPC computing and Linked Open Data technology to predicting forest fires behaviour and spreading.

In this section, we present the pilot objectives and requirements, and we describe the developments and tests performed for this first iteration. The different stages of the developments, and the test planned until the end of the project are also included.

3.1.1 Objectives

The aim of FRAME (Forest fiRes Advanced ModElization) is to improve forest fires prevention and control, as well as to mitigate consequences. It focuses on using a HPC-adapted propagation model for predicting forest fires behaviour and spreading according to high spatial and time resolution data related to weather (wind, temperature and humidity), vegetation and terrain, available or enhanced from public open data infrastructures from Portugal and Spain for a cross-border approach. FRAME will consider both fire spread parameters and performance of fire-fighting measures. (Figure 6)

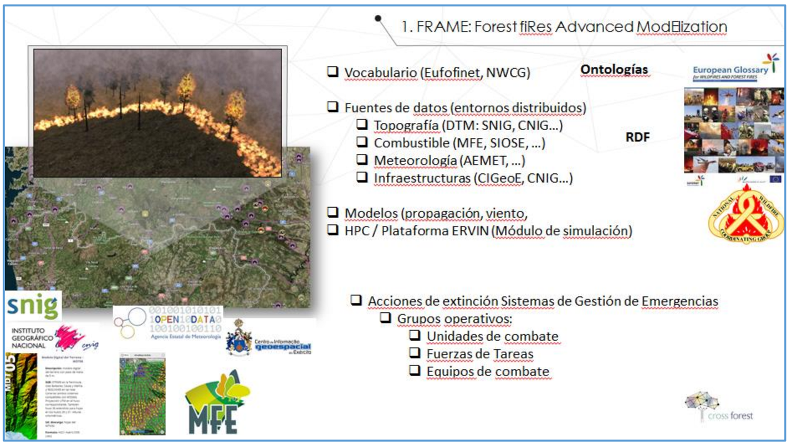

Figure 6 FRAME general scheme

In the FRAME pilot, simulations of forest fire behaviour will be carried out on real scenarios where fire will propagate over cell sizes of one square metre spatial resolution. Over these simulations, as a novelty respecting other pre-existing systems, on real time combat actions could be performed, as well as modifications of meteorological conditions, across a wide area of susceptible burning. Input values, which means digital elevation model (DEM), roads and infrastructures, fuel models and meteorological data, will be obtained from Open Data published by different public administrations. In particular, FRAME expects to achieve fuel data from the Linked Open Data that the CrossForest project itself will provide as a final outcome, especially those from the Spanish and Portuguese forestry maps, in order to demonstrate how this linked data can help to settle some lacks in this matter.

Specifically, a modification of the propagation core developed in the wildfire virtual trainer ERVIN (Gonzalvo et al. 2017) is used as the basis to develop FRAME propagation model, running over a HPC environment, and employing the emergencies and wildfire management system EMERCARTO (Gonzalvo et al. 2017) developed by Tragsa Group as the user interface.

Simulation will enclose steps as follows:

1. Choice of area or plot for subsequent simulation.

2. Choice of points or lines of ignition.
3. Execution of fire propagation model based on the input open data gathered.
4. Modification of meteo conditions as well as combat actions over the proposed scenario at simulation proceeding.

In summary, in FRAME pilot it is intended to reach a wildfire simulation, not constricted to spatial limits, on which extinction actions and adjustments to the starting conditions can be executed on the fly, on different operational scenarios, taking advantage of the capacities of the HPC supercomputing environment.

3.1.2 Pilot requirements

A first approach to the pilot requirements was defined in "D3.1 User Specifications and Requirements v1.0". As a consequence of the progress in Activity 3, there has been an evolution of FRAME requirements.

These requirements definition process has involved a multidisciplinary approach between the different professional profiles working jointly in the pilot development. Requirements have been defined much more in depth from a technical point of view, and organizational aspects have been considered as well.

Several requirements refer to EMERCARTO. As it was explained in the former section, it is an emergencies and wildfire management system, which will be FRAME's users interface.

FRAME pilot is divided in three stages, according to the expected development evolution. Final results are expected to be reached in three iterations.

FRAME requirements in their current state of definition are presented in the sections below, which include: (i) pilot requirements for Stage I, Stage II and Stage III, (ii) external datasets and (iii) data transformation. The original tables can be found in annexes IV to VI at the end of document.

The tests executed in this "First trial" (M18) cover the requirements from 0 to 6, which are those included in Stage I.

3.1.2.1 Stage I: Iteration 1 - month 18 – February 2020

Requirement 0 Cell matrix definition

Description/Motivation	User defines cells matrix in order to be filled with data during next steps
Pre-condition	Tile definition
Normal sequence steps/actions	User defines cell matrix: corner coordinates, cell size and quantity
Postcondition	Cell matrix defined for simulation in Stage I

Requirement 1 Fire starts: points and/or perimeter ignition

Description/Motivation	User defines points of initial ignition in order to be used in simulation
Pre-condition	Defined cell matrix is loaded

Normal sequence steps/actions	User defines ignition points in cell matrix
Postcondition	Ignition points sending to propagation core

Requirement 2 Located Area Data Loading: DEM

Description/Motivation	Propagation core needs terrain height data for simulation, assigned in this stage for the area defined by cell matrix
Pre-condition	Local data input origin from predefined scenario
Normal sequence steps/actions	Propagation core loads terrain height data
Postcondition	Terrain, roads and infrastructures, meteo and fuel models data are assigned to each cell in matrix

Requirement 3 Located Area Data Loading: roads and infrastructures

Description/Motivation	Propagation core needs infrastructures data for simulation, assigned in this stage for the area defined by cell matrix
Pre-condition	Local data input origin from predefined scenario
Normal sequence steps/actions	Propagation core loads infrastructures data (roads, trails, firebreaks, edification…)
Postcondition	Terrain, roads and infrastructures, meteo and fuel models data are assigned to each cell in matrix

Requirement 4 Located Area Data Loading: meteo data

Description/Motivation	Propagation core needs meteo data for simulation, assigned in this stage for the area defined by cell matrix
Pre-condition	Local data input origin from predefined scenario
Normal sequence steps/actions	Propagation core loads meteo data (air temperature, wind spread and direction, relative air humidity)
Postcondition	Terrain, roads and infrastructures, meteo and fuel models data are assigned to each cell in matrix

Requirement 5 Located Area Data Loading: fuel models

Description/Motivation	Propagation core needs fuel data for simulation, assigned in this stage for the area defined by cell matrix
Pre-condition	Local data input origin from predefined scenario

Normal sequence steps/actions	Propagation core loads fuel model data (variables defined in propagation core)
Postcondition	Terrain, roads and infrastructures, meteo and fuel models data are assigned to each cell in matrix

Requirement 6 HPC Computing

Description/Motivation	Propagation core runs with alternative parameters over HPC Calendula of Scayle in order to demonstrate the parallelism capacities
Pre-condition	Cell matrix, input data and ignition points loaded on HPC
Normal sequence steps/actions	Propagation core runs on HPC Calendula
Postcondition	Active cells by time output files

3.1.2.2 Stage II: Iteration 2 - month 25 – September 2020

Requirement 7 Mapping of fire perimeters in Emercarto

Description/Motivation	Output from HPC Calendula is converted to perimeter polygon layer and showed in wildfire management system EMERCARTO
Pre-condition	Output results from simulation executed in HPC Calendula: fire perimeters
Normal sequence steps/actions	Calendula output files are vectorised in fire polygons suitable to EMERCARTO
Postcondition	Visualization of fire polygons in EMERCARTO (perimeters layer)

Requirement 8 Extensive Data Loading: DEM

Description/Motivation	System incorporates topographical (Digital Elevation Model) data available from open resources by public administrations in Spain and Portugal.
Pre-condition	Updated links to DEM information
Normal sequence steps/actions	Loading data from local/online sources in a specific surface and propagation core running in HPC Calendula
Postcondition	Updated terrain, roads and infrastructures, meteo and fuel models data and fire perimeters

Requirement 9 Extensive Data Loading: roads and infrastructures

Description/Motivation	System incorporates infrastructures data available from open resources by public administrations in Spain and Portugal.
Pre-condition	Fuel model data to overwrite and link to infrastructure information
Normal sequence steps/actions	Loading data from local/online sources in a specific surface and propagation core running in HPC Calendula
Postcondition	Updated terrain, roads and infrastructures, meteo and fuel models data and fire perimeters

Requirement 10 Online Data Loading: meteo data

Description/Motivation	System incorporates meteo data (prediction/historical) from online resources by public administrations.
Pre-condition	Online connection to meteo data providers (AEMET and others)
Normal sequence steps/actions	Loading data from local/online sources in a specific surface and propagation core running in HPC Calendula
Postcondition	Updated terrain, roads and infrastructures, meteo and fuel models data and fire perimeters

Requirement 11 Extensive Data Loading: fuel models from LOD

Description/Motivation	System incorporates fuel data available from open resources by public administrations in Spain and Portugal.
Pre-condition	Connection to the Spanish Forestry Map Linked Open Data and Forest cartography from Portugal provided at CrossForest endpoint
Normal sequence steps/actions	Loading data from local/online sources in a specific surface and propagation core running in HPC Calendula
Postcondition	Updated terrain, roads and infrastructures, meteo and fuel models data and fire perimeters

Requirement 12 Extensive Data Loading: fuel models from regional Administrations

Description/Motivation	System incorporates fuel data available from open resources by regional administrations in Spain (Autonomous Communities) and Portugal if available.
Pre-condition	Fuel data availability for some regional areas
Normal sequence steps/actions	Loading data from local/online sources in a specific surface and propagation core running in HPC Calendula

Postcondition	Updated terrain, roads and infrastructures, meteo and fuel models data and fire perimeters

3.1.2.3 Stage III: Iteration 3 - month 30 – February 2021

Requirement 13 EMERCARTO connection: fire start points or perimeter

Description/Motivation	Provide EMERCARTO with edition tools which captures and sends ignition points to FRAME propagation system
Pre-condition	Creation of EMERCARTO edition tools
Normal sequence steps/actions	Fire ignition points or perimeters are drawn in EMERCARTO and simulation is started
Postcondition	FRAME calculates propagation and returns fire perimeters to EMERCARTO

Requirement 14 EMERCARTO connection: combat actions

Description/Motivation	Provide EMERCARTO with edition tools which capture and send combat actions in real time to FRAME propagation system
Pre-condition	EMERCARTO-Calendula communication: visualization of fire perimeters in EMERCARTO
Normal sequence steps/actions	Combat actions in real time are drawn in EMERCARTO and simulation is recomputed
Postcondition	FRAME updates propagation and returns fire perimeters to EMERCARTO

3.1.2.4 External datasets

Regarding external datasets, it is necessary to mention that only Spanish databases are included so far in the table below. In coming stages, Portuguese databases will be added. The original table can be found in annex V at the end of document.

Table 2 FRAME external datasets.

Themes	Variables	Data sources: Spain
DEM (digital elevation model)	Individual defined cell height	http://centrodedescargas.cnig.es/CentroDescargas/index.jsp
		Regional cartography services
Forestry map (fuel layer)	Fuel Load, Combustibility, Spread rate, Tool Integrity	Spanish National Forestry Map
		Spanish National Forestry Inventory
		http://www.aemet.es/es/datos_abiertos/AEMET_OpenData

Meteo historic and real time updates	Temperature, Relative Humidity, Wind direction, Wind spread	Regional meteo systems
Roads and infrastructures	Individual defined cell assignment	http://centrodedescargas.cnig.es/CentroDescargas/index.jsp
		Regional cartography services
		https://eurogeographics.org/products-and-services/open-data/topographic-data/

3.1.2.5 Data transformation

Below it is showed some of the specific end-user questions that FRAME must be capable to answer, by the way of processing outcomes or execution parameters. The original table can be found in annex VI at the end of document.

Table 3 FRAME data transformation considered.

Questions	File/Database required	Processing rules
What will be fire perimeter at the hour "x"?	FRAME cells status	Active cells
Will fire reach a specific point? At which hour?	FRAME cells status	Will the cell reach active state and at which moment
What will be flame length or fire intensity at a specific point and hour?	FRAME cells status	Intensity value of cell at a certain place and at any given time
What will be rate of spread at a specific point and hour?	FRAME cells status	Rate of spread value of cell at a certain place and at any given time
Will fire exceed track or barrier, "x" meters wide, in his predicted progress?	FRAME cells status	Intersection between selected firebreak and fire perimeter of active cells
Will municipality X be affected? Such a natural space? In which proportion?	FRAME cells status/ EMERCARTO DB	Intersection of EMERCARTO layers with active and burned cells
Which roads or paths will intersect the predicted progress of fire?	FRAME cells status	Touch of roads or paths cells with active and burned cells
What will be the affected surface at a specific moment?	FRAME cells status	Total amount of burned cells

What will be maximum registered fire intensity and rate of spread? At what points?	FRAME cells status	Cells with highest I or Vp
Wind direction or slope at a certain place and at any given time?	FRAME cells status	Cell slope and wind direction values
What is the type of vegetation at a certain place and at any given time? What percentage of burned area, according to the type of vegetation, will be affected in each case?	FRAME cells status/ EMERCARTO DB	Intersection of EMERCARTO layers with active and burned cells
Within an active perimeter at a given time, which is the most active point, that is, with higher rate of spread or fire intensity?	FRAME cells status	Highest I or Vp in active cells

3.2 Preparation

3.2.1 Schedule

FRAME workflow is shown in figures 7 and 8, and described in the next paragraphs.

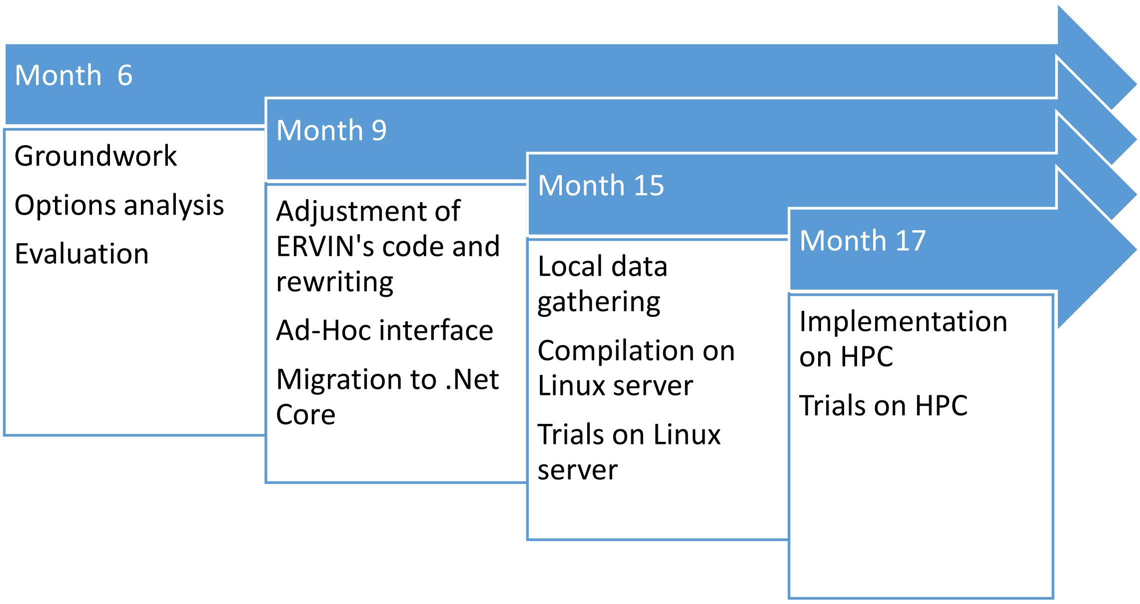

Figure 7 FRAME schedule up to M18

On the sixth month of Cross-Forest (M6), actions of groundwork and analysis of different alternatives for the intended aim of reproducing ERVIN’s propagation core on the HPC environment begin. A first approach determined that the migration of ERVIN’s code from C# language to C++ was needed, in order to take advantage of the resources of supercomputing on Linux system of HPC Calendula, although finally the interim solution of adapting compilations to .Net Core software was assumed.

The process of ERVIN’s code rewriting began on M9. This task represents the main issue to be faced in FRAME development, as it is presumed to persist during the whole evolution of the works, during which several adjustments and modifications are expected to be solved. From M9 on, a personal interface designed for trials purposes, and the actions to operate with .Net Core software are implemented.

M15 and M16 are focused on the goal of getting the system to interpret local data (meteorological, topographical and fuel data), in formats that the sources of public administrations will provide afterwards. A first FRAME version in a pre-production Linux server is compiled, in which several trials are carried out.

M17 and M18 are dedicated to implement FRAME propagation core in HPC Calendula and to test performance and adequacy of outcomes.

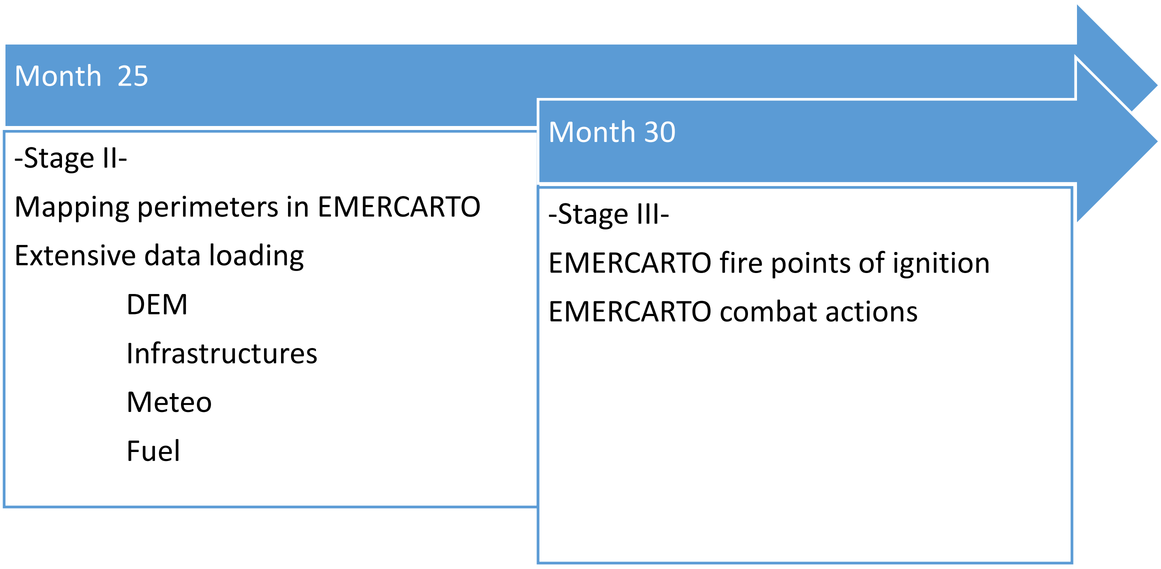

Figure 8 FRAME schedule from M18 to end

From month 18 in advance, remaining stages will be completed (figure 8).

Extensive data loading, that comprehends all works related to access to online data sources and its treatment by the propagation core, is intended to be finished by the end of month 25. This stage also includes the functionality of sending the outcome perimeters of simulation to EMERCARTO interface and their representation over the EMERCARTO cartographic tools.

Stage III comprises tasks involved in showing advance of fire simulation in the online EMERCARTO interface mentioned and to incorporate tools to allow final user incorporate input data to system, like initial ignition points or weather parameters, as well as to modify propagation of fire by including combat actions just as simulation goes on.

3.2.2 Pilot Development

Overview

Once implemented the first version of propagation core, there is available a simulation process that includes variables of air temperature and relative humidity, wind spread and direction, fuel models parameters and digital elevation model (DEM). This version does not support Geographical projections or Datum, like WGS84 or ETRS89, so it was not necessary to develop the relationship between terrain coordinates and simulation DEM.

Tasks implemented at first iteration and works performed are listed below.

Requirement 0 Cell matrix definition

Considering that propagation core works over a cell matrix with tiles of 1x1 meters, the way to designate the matrix where simulation will take place is developed, by input parameters, width, length and number of tiles.

Once verified that propagation core uses correctly the external data denoting width, length and number of tiles in the matrix, the modules that establish the relationship between terrain coordinates and simulation matrix are developed, so user can define terrain coordinates (WGS84 latitude and longitude) over simulation will be conducted.

Requirement 1 Fire starts: points and/or perimeter ignition

It is allowed to signify, by input parameters, the ignition points. Those points are position of tiles in the cell matrix.

Applying the modules that establish the relationship between terrain coordinates and simulation matrix, it is allowed to signify ignition points by terrain coordinates (WGS84 latitude and longitude).

Requirement 2 Located Area Data Loading: DEM

At the beginning, it is allowed to signify, by input parameters, just one DEM at each execution.

In a second stage of development of this functionality, the necessary developments are carried out for the accurate reading of DEM data downloaded from IGN (cartography provider of Spanish National Administration). In this way, it is possible to assign to each tile in cell matrix its corresponding actual height.

Requirement 3 Located Area Data Loading: roads and infrastructures

At this stage, it is allowed to signify, by selecting specific tiles in cell matrix, the areas of incombustible ground denoting roads, buildings and wildfire infrastructures of defence as firebreaks or paths.

Requirement 4 Located Area Data Loading: meteo data

At start of execution, it is allowed to signify the following meteorological parameters: relative humidity, air temperature, wind spread and wind direction. In current version, those parameters are the same to the whole cell matrix defined and remain constant during the course of simulation.

Requirement 5 Located Area Data Loading: fuel models

It is allowed to signify a single fuel model in an execution. Such model is applied to the whole cell matrix defined, regardless of the position of each tile. Collection of fuel model according with its actual position from linked open data, such as Spanish Forestry Map, is a task that will be adopted in the next iteration of FRAME pilot, considering that these linked data will be provided as an outcome of CrossForest project.

Requirement 6 HPC Computing

Before deploying propagation core in HPC Calendula, the executable files for trials in Linux environment are arranged by the development team.

Once verified the optimal working in Linux environments by the development team, several tests are performed in HPC Calendula machine.

Setup

Configuration of propagation core is established for each simulation. In current version, execution setup of each simulation consists of a text file in which is defined:

- Meteorological variables like relative humidity, air temperature and wind spread and direction.
- Terrain coordinates throughout the simulation will take place (xMinimum, yMinimum, xMaximum, yMaximum, latitude and longitude in WGS84)

- Route pointing data of DEM (Digital Elevation Model)

3.2.3 Input data

The configuration file for an execution consists of the next input data:

- Terrain range
- Ignition points
- Meteorological variables like relative humidity, air temperature and wind spread and direction.
- DEM files downloaded from IGN (cartography provider of Spanish National Administration), that contain terrain height within 5 meters (Figure 9).

```
ncols         400
nrows         400
xllcorner     342067,5
yllcorner     4457852,5
cellsize      5
NODATA_value  -9999
682,462 679,58 674,938 671,946 669,375 666,773 666,211 664,63 663,648 663,146 662,775 662,393 662,281 662,03 661,208 660,396 660,185 659,293
682,212 679,93 675,948 672,546 669,645 666,813 665,801 664,62 663,778 662,406 661,975 661,833 661,371 660,89 660,328 660,176 659,925 658,903
682,002 679,66 676,188 673,236 670,265 667,373 666,571 664,98 663,428 662,356 661,955 661,363 660,901 660,46 660,108 659,936 659,775 658,823
681,842 679,47 676,268 673,346 670,225 668,213 666,671 665,28 663,158 662,426 662,064 661,783 660,691 660,06 659,448 659,646 659,115 658,313
681,182 680,18 676,838 673,936 671,045 668,183 665,521 664,779 663,488 661,956 661,274 660,043 659,481 659,41 659,188 658,586 658,315 657,903
680,542 679,9 677,178 674,366 672,005 668,903 664,971 664,249 662,978 662,036 660,874 660,493 659,271 658,999 658,568 658,466 658,015 657,763
679,691 679,06 677,948 674,946 672,605 667,243 665,471 663,749 662,818 661,436 660,834 660,683 658,701 658,489 658,328 657,346 657,425
678,541 678,16 677,778 675,106 673,204 667,853 665,321 664,799 662,748 661,176 660,724 660,643 660,591 658,019 657,268 656,966 656,155
678,251 677,78 677,068 674,386 671,314 667,513 665,611 663,979 662,758 661,766 660,644 660,523 659,651 657,969 657,178 656,106 655,725
678,011 676,88 676,278 672,676 670,694 668,703 666,571 664,369 662,418 661,966 660,514 660,313 659,291 657,799 656,878 656,516 655,234
677,881 676,53 675,648 672,526 669,934 668,203 666,521 663,759 662,068 661,976 660,664 660,493 659,851 658,049 657,668 656,576 655,204
677,511 675,769 675,038 672,706 670,584 667,193 664,501 663,239 662,178 661,986 660,904 660,613 660,211 658,079 658,048 656,596 655,884
677,111 675,179 674,308 671,966 670,074 668,103 664,931 663,619 663,017 661,796 661,054 660,332 659,821 658,499 657,508 656,576 655,974
676,731 674,889 673,788 671,396 668,724 667,243 665,981 663,929 662,767 661,416 661,084 660,172 659,831 658,819 658,088 656,966 656,294
676,641 674,559 673,098 671,046 669,464 667,722 665,851 664,049 662,987 662,416 661,444 659,992 659,851 659,019 658,838 657,216 656,394
675,931 673,589 672,428 670,916 669,694 668,052 665,821 664,329 663,187 662,076 661,434 660,962 660,261 659,449 658,407 658,006 656,764
675,171 672,799 671,958 670,686 669,064 667,412 666,391 665,179 664,297 662,626 661,804 660,882 659,891 659,069 658,137 657,376 656,734
674,001 672,099 671,238 669,876 668,864 667,692 666,671 665,469 663,757 663,056 662,364 661,292 659,821 659,009 657,857 657,016 656,194
671,911 671,719 670,547 669,436 668,664 668,202 667,191 665,589 663,997 663,436 662,884 661,592 660,251 659,259 658,017 657,226 655,954
671,871 670,419 669,837 668,626 668,124 667,942 666,621 664,869 663,777 663,686 663,124 661,922 661,131 659,739 658,247 657,366 656,134
671,281 669,659 669,237 668,406 667,664 666,922 665,671 663,999 663,767 663,725 663,304 662,062 660,741 659,439 657,997 656,956 655,844
670,761 669,409 668,817 668,176 667,024 666,092 664,67 664,149 663,997 663,475 662,984 661,962 660,09 659,089 657,897 656,556 655,174 653,812
670,281 668,579 667,967 667,586 666,764 665,502 664,44 664,219 664,237 662,715 662,504 661,392 660,83 659,439 657,787 656,326 655,224 653,922
669,771 668,109 667,247 667,056 665,814 665,152 664,37 664,449 662,807 661,845 661,924 661,292 660,74 659,519 657,297 655,406 654,224 653,422
669,181 667,989 667,297 666,135 665,474 664,902 665,05 663,709 662,047 661,675 661,594 660,982 660,63 658,929 655,947 654,496 654,124 653,692
668,711 668,359 667,347 666,555 665,464 665,322 663,64 663,069 662,167 661,225 660,984 660,752 659,24 656,799 655,117 654,685 653,364 652,702
669,171 668,519 667,177 665,825 665,044 664,152 662,96 662,489 661,697 661,015 660,734 660,162 658,48 656,939 655,727 654,235 652,884 651,862
669,161 668,519 666,507 664,795 664,174 663,492 663,13 662,749 662,017 661,175 660,384 659,422 658,66 656,789 655,607 655,775 653,334 652,282
668,951 668,649 667,817 666,675 664,894 664,052 663,77 663,199 662,367 661,205 660,544 659,532 658,24 657,089 656,317 655,605 653,984 653,392
669,33 667,889 668,487 667,205 665,594 664,582 664,44 663,498 662,267 661,105 660,303 659,422 659,67 658,929 657,757 656,195 655,144 653,292
668,75 668,669 668,417 666,925 665,834 665,672 664,37 663,508 662,197 660,845 659,713 659,562 659,46 658,039 657,197 655,965 655,444 653,522
668,7 668,499 667,717 666,955 666,133 665,322 664,42 662,878 661,567 661,005 659,773 658,582 658,53 657,308 656,727 656,075 655,624 653,532
668,67 668,559 667,567 666,975 666,393 665,392 663,55 661,878 661,127 659,865 658,773 657,882 657,5 657,308 655,957 655,045 654,354 652,982
668,65 668,199 667,507 666,695 665,893 664,492 662,8 661,378 659,957 658,735 658,023 657,242 656,86 655,858 655,047 654,375 653,804 652,622
668,3 667,609 667,177 666,515 665,283 663,822 662,21 660,878 659,447 658,305 657,333 656,592 656,01 655,408 655,047 654,105 653,754 652,302
667,53 667,438 666,797 666,835 665,183 662,432 661,51 660,158 659,277 658,485 657,323 656,232 655,75 655,198 654,097 653,585 652,823 651,592
667,46 666,838 666,677 666,955 664,163 662,282 661,13 660,108 658,987 658,325 657,353 656,442 655,88 654,408 653,367 652,565 651,633 651,642
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666,6 666,398 665,957 664,205 663,453 662,251 661,1 660,238 659,416 658,525 658,023 657,031 656,19 654,508 653,377 651,665 651,023 649,772
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661,43 662,868 661,906 661,115 660,793 659,441 658,259 656,798 655,926 654,984 653,033 652,351 651,03 649,458 648,716 648,225 647,503 647,082
660,48 660,328 660,356 660,345 659,483 659,031 657,319 656,318 655,506 653,924 652,693 651,341 650,19 648,838 648,276 647,505 647,423 646,571
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657,36 657,598 657,276 658,234 657,003 655,701 655,129 654,148 653,216 652,584 651,173 649,661 648,569 647,748 647,176 646,725 646,543
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655,11 655,278 655,356 655,594 654,863 653,971 652,829 652,348 651,786 651,824 650,873 648,441 647,989 647,188 646,956 646,185 645,163
654,79 654,408 654,596 654,764 654,693 653,661 651,809 651,158 651,506 651,544 649,443 648,571 647,499 646,938 646,646 646,204 644,813
654.449 654.638 654.256 654.014 652.603 653.131 652.039 650.148 649.996 649.444 648.093 647.761 647.049 646.568 646.166 645.614 645.123
```

Figure 9 Example of ASCII file representing terrain from IGN

3.2.4 Strategies used and problems faced

The development has been carried out in .Net Core software, since it allows multiplatform compilations. In this manner, it has been possible to create a specific compilation to be able to run on Linux servers (HPC Calendula).

As indicated at previous sections, throughout developments it is intended to separate calculation module that takes part of propagation core, from external data that cited module requires. Because of this independence, it is expected to dispose a propagation core that requires minimal changes, leaving both duties related to reading and accessing data and duties related to writing and results analysis, in hands of another micro services.

Main issues faced:

- First tests of execution in Linux did not work correctly due to non-updated versions of .Net Core development environment. After .Net Core updating and employing self-containing compilations, Linux executions took place properly. When using self-containing compilations it is not necessary to achieve Linux installations related to different versions of .Net Core, because the code deployed contains everything that is needed for its execution, including libraries from .Net Core version used.
- Handling and reading of large files containing height data. Analysis and checks, with diverse interpolation methods, to obtain height for a given point.
- Adaptations and adjustments in calculation of propagation core, due to diverse understanding of wind direction concept with respect to angle concept in mathematics calculations (origin and positive bearing of angle differs between both systems).

3.3 Execution

3.3.1 Test execution

Tests were carried out according to the schedule formerly presented, and following the Continuous Integration (CI)* methodology, as this makes it possible to detect eventual bugs in the course of development. Applying this method means that tests are carried out on every step of the development process, so that any change in code or any compilation results in an evaluable outcome.

> **Continuous Integration (CI) is the process of taking features from the Program Backlog and developing, testing, integrating, and validating them in a staging environment where they are ready for deployment and release. Due to rapid integration of code, it is more likely that defects surface faster than it could compare to normal manual integration and reduces manual testing effort. Furthermore, it provides a facility of falling back to previous versions in case of any problem to the current build.*

Some of the continuous evaluation tests performed throughout the development process are:

- Execution test within a specific cell's matrix and particular ignition points. It is verified that, after the execution, the propagation core has burnt all the cells in matrix and the burning times reflect the advance of the fire properly.
- Replication of same test over the same terrain extension, varying the variables of fuel model. By doing so, it is intended to corroborate the accurate propagation of fire relative to fuel model.
- Replication of same test over the same terrain extension, varying the digital elevation model. By doing so, it is intended to corroborate the accurate propagation of fire relative to slope factor, determined from height.
- On a digital elevation model is tested the access checking, the calculation of height and the calculation of derived slope from mentioned height.
- Execution test in HPC Calendula. It is verified that application runs properly in HPC Calendula and some outcomes are obtained.

Tests execution is carried out in two distinguished environments:

- Linux server from development and trials team (TRAGSATEC). Characteristics of Linux server used in tests are:
    - Processor: 2vcpu
    - RAM memory: 4 GB
    - Disk capacity: 48 GB
    - Operation system: SUSE Linux Enterprise Server 12 SP3

- HPC Calendula. The computing infrastructure used in tests, in this particular case is the Haswell architecture which has 114 servers with the following technical specifications:
    - 2 Intel Xeon E5-2630 v3 processors (Haswell) 8 cores @ 2.40 GHz
    - 32 GB RAM
    - Infiniband interface FDR 56Gb/s

3.3.2 Results

After the execution of the mentioned tests, results show the following:

- When performing a simulation within a determined extension of terrain, simulation finish when the whole extension of terrain is consumed (burned). Burning time in each cell reflects, as expected, the rate of spread of fire.
- When running simulations varying fuel model, the rate of spread of fire denote a variation according to diverse input parameters of fuel model applied.
- Tests over several terrain extensions and digital elevation models, reflects accurately the influence of height model over the progress of fire.
- After running a test battery on the development's Linux server (Figure 10), running the same test sequence on HPC Calendula, significant improvements in execution times are observed when using supercomputing. On the other hand, it's observed that, in the course of HPC Calendula executions, propagation core uses the full power of data processing that Calendula provides, that means, that during running it employs all of the 16 cores that server offers.

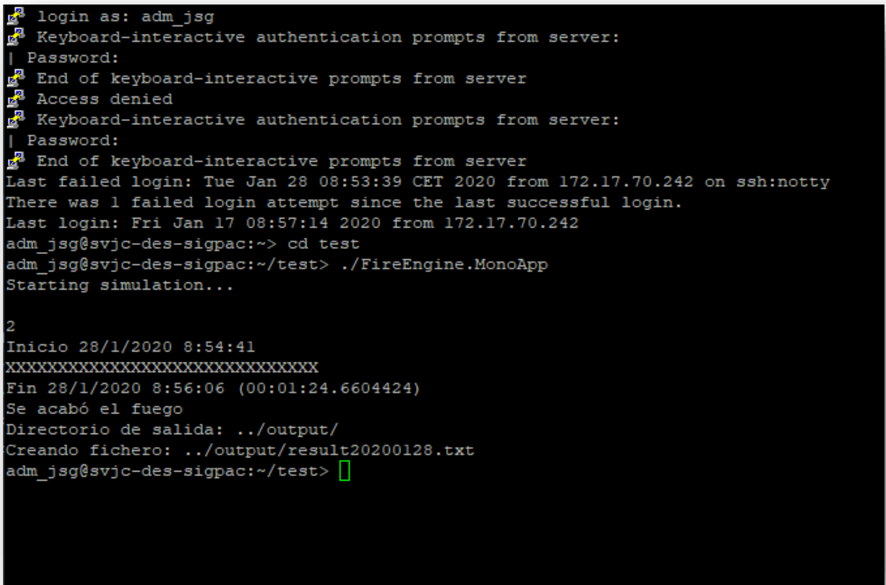

Figure 10 Log of simulation activity on Linux server, success status

3.3.3 Reported data: files, formats, etc.

The execution of the simulation currently produces a unique “results file”. The content of this “results file” has suffered changes, so to adapt it to the Project’s needs, according to the CI methodology.

Nowadays, the main characteristics of the “results file” are:

- ASCII format
- Contains information about the date and time in which the combustion of each cell has taken place > time measurements for the combustion of 1x1 m tiles (see figure 11).

Additionally, an *Ad-hoc* application has been developed, which allows loading and visually checking the content of the “results file”, so to make it easier to interpret the evolution of the fire. It also shows information about the time required for the whole simulation (see figure 12)

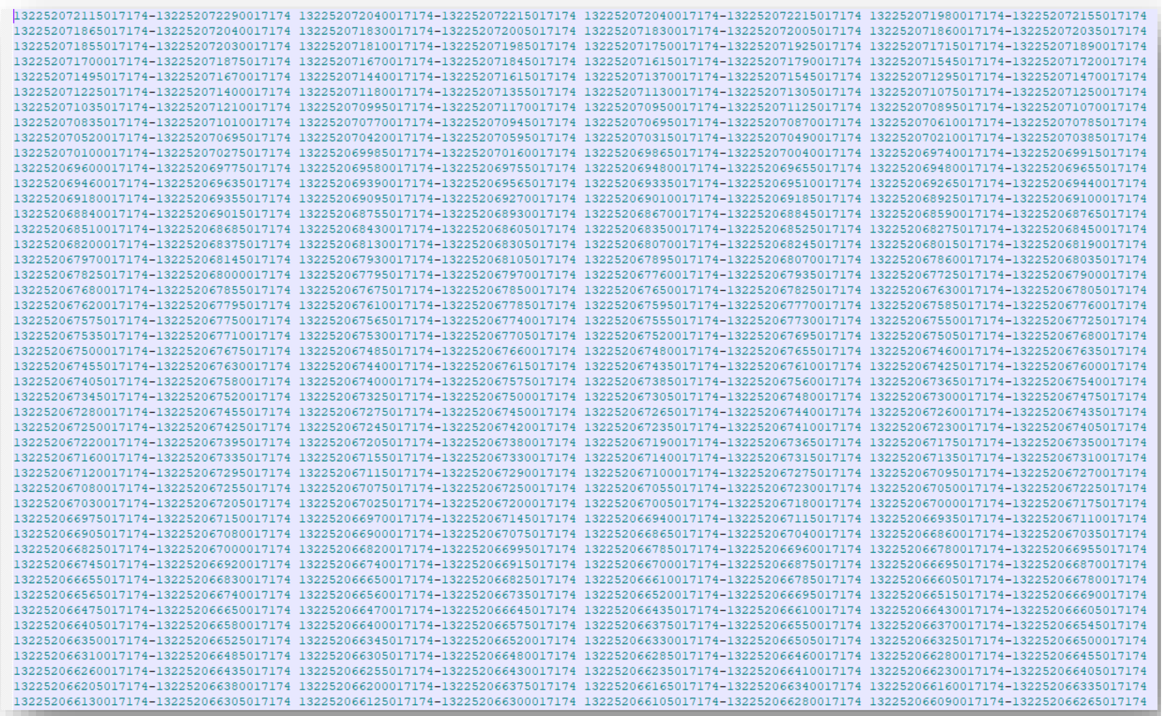

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Figure 11 Output matrix of cells, status over time

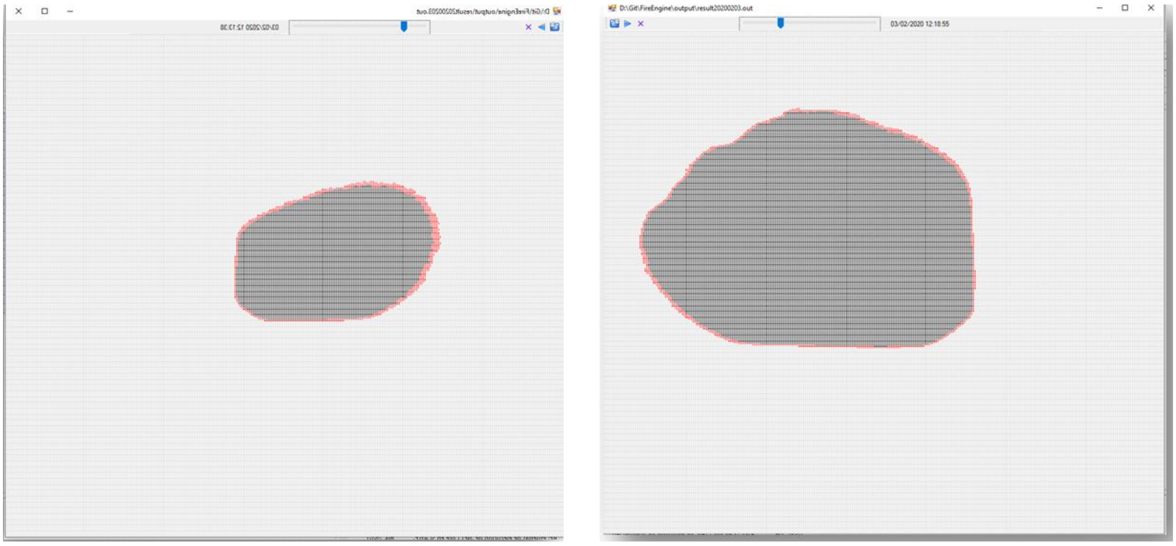

Figure 12 Ad-hoc interface for testing evolution of fire

Recommendations regarding reporting: lessons learned for the next pilot iteration regarding how to report results.

As it has been observed during the development phases, for the next iterations it is necessary to enlarge the amount of results obtained from simulation executions. It can be performed by broadening the content of the current “results file” or by generating new “results files” which complement the current one.

The increase of information obtained as the result of an execution of the simulator, will probably be related with issues such as:

- Relevant information regarding new input (i) data layers or (ii) data Services, which will be include in the simulation process (vegetation height, meteo data, combustion and terrain characteristics…).
- Register of other simulation features (flame maximum height…)
- Affected surface from a certain vegetation type.
- ….

3.3.4 Strategies used and problems faced

As explained in the precedent section, the strategy carried out is the utilisation of continuous integration as the methodology for testing purposes.

With regard to problems faced, considering continuous integration, they can be considered as included in section 3.2.4.

4 Final remarks

As provided for in the Grant Agreement, *Activity 3 "will evaluate the Cross-Forest HPC infrastructure and datasets (implemented in Activity 2) through the development and deployment of two advanced demonstrators working on HPC environments: the use cases (or pilots) FRAME and CAMBrIc. The pilot applications will be developed by pilot providers (TRAGSA, UVa) and Data providers (TRAGSA, DGT) with support of technological partners (SCAYLE)".*

The starting phases of Activity 3 have required a big effort, and it is necessary to point out that developments for the implementation of the pilots are delayed. All involved partners are working in collaboration and efforts are being intensified to face the second period of the project.

Despite of that, for this first trial of the project, very important advances have been made from UVA and TRAGSA (with support from other partners and collaborators) for the adaptation of the algorithms for running in a HPC environment and the performance of tests:

- For CAMBRIC, SIMANFOR simulator code has been completely modified in a different environment and language to make it compatible with the HPC environment.

  Local tests are currently running on a Linux PC and first tests on Calendula are about to be performed (planned for mid-March).

- For FRAME, the refactoring of the fire propagation simulator code from C# to a Linux-compatible version has been completed.

  Local tests have run on a Linux server, and a first test on Calendula has been successfully performed, making an optimized use of the HPC resources.

Results from the different tests performed in this first iteration for CAMBRIC and FRAME are not homogeneous for both pilots, and they must be considered as preliminary, as well as the derived tentative conclusions.

As stated in the project planning, results and conclusions from this first trial are included in "Deliverable 4.3 Evaluation of results - Interim Report".

Facing the second period of the project, intermediate iterations have been planned for CAMBRIC and FRAME (see schedule sections 2.2.1 and 3.2.1). Based on the feedback collected in this first iteration and the intermediate ones, the final iteration of pilots will provide final prototypes for their evaluation and testing, with the aim of validating the Cross-Forest infrastructure in real case studies.

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Cross-Forest “D3.1 User specifications and Requirements v1.0”

Definitions, acronyms and abbreviations

AEMET	Spanish Meteorological Agency
CALENDULA	Supercomputer located at SCAYLE
CAMBRIC	CAlidad de la Madera en Bosques mIxtos (Wood quality in mixed forest)
CBD	Crown Bulk Density
CEF	Connecting Europe Facility
CFIS	Crown fire initiation and spread
CI	Continuous Integration methodology system
CORDIS	Community Research and Development Information Service
DEM	Digital Elevation Model
DGT	Direção-Geral do Território
DTM	Digital Terrain Model
EC	European Commission
EMERCARTO	Emergencies and wildfire management system
ERVIN	Virtual Trainer for Wildfires
EU	European Union
FRAME	Forest fiRes Advanced ModElization
GIS	Geographic information system
HPC	High performance Computing
ICT	Information and communications technology
ICNF	Instituto de Conservação da Natureza e Florestas
IGN	National Geographic Institute (Spain)
INEA	Innovation and Networks Executive Agency
IPMA	Portuguese Institute for the Sea and Atmosphere
LiDAR	Laser Imaging, Detection And Ranging
LOD	Linked Open Data
MAPA	Agriculture and Environment Ministry (Spain)
NFI	National Forest Inventory
SCAYLE	Fundación Centro de Supercomputación Castilla y León (Castilla y León Supercomputing Center)
SIMANFOR	Support system for simulating Sustainable Forest Management Alternatives
TRAGSA	Empresa de Transformación Agraria, S.A.
UCO	University of Córdoba
UVA (IuFOR)	University of Valladolid (Institute for Research in Sustainable Forest Management)
UVA (GSIC/EMIC)	University of Valladolid (Group of Intelligent & Cooperative Systems / Education, Media, Informatics & Culture)

Annexes

Annex I CAMBRIC requirements, general table

Requirements	Use Case	Short Title	Description/Motivation	Pre-condition	Normal sequence steps / actions	Postcondition
0	CAMBRIC – Input Data Definition	Tree Identification. Compulsory	Code to identify every tree in the inventory	Stored in IFN for each tree	Should be included in the dataset.	Stored in Cross-Forest dataset.
1		Tree species. Compulsory	Species identification of every tree in the inventory	Stored in IFN for each tree	Should be included in the dataset.	Stored in Cross-Forest dataset.
2		Tree age. Compulsory	Tree age is necessary for quality assessment and identification of evolutionary status of the stand	If the tree age is not available in the dataset it has to be estimated	Estimate lacking ages and assign way of calculus in a new variable.	Stored in Cross-Forest dataset.
3		Tree relative position in the plot / Absolute position. Optional	Information necessary for competition assessment at tree level.	Stored in IFN for each plot	Should be included in the dataset.	Stored in Cross-Forest dataset.
4		Dendrometric: Tree size (measured). Compulsory	diameter, height (total, base crown,…), …	Diameter and total height stored in IFN for each plot, the other variables should be estimated	Estimate all variables we need to include in the growth model. It depends on each species.	Stored in Cross-Forest dataset.
5		Dendrometric: Tree size (calculated/estimated). Compulsory	volume, biomass, carbon,…	Estimation required	Estimate. It depends on each species.	Stored in Cross-Forest dataset.
6		Plot absolute position. Compulsory	Necessary for geographical analysis	Stored in IFN for each plot	Should be included in the dataset	Stored in Cross-Forest dataset.

Requirements	Use Case	Short Title	Description/Motivation	Pre-condition	Normal sequence steps / actions	Postcondition
7		Dasometric: plot density (Measured). Compulsory	Trees per hectare, basal area	Stored in IFN for each plot	Should be included in the dataset	Stored in Cross-Forest dataset.
8		Dasometric: plot density (Calculated). Optional	Stand density index, Hart index, canopy cover,…	Calculus required	Calculate.	Stored in Cross-Forest dataset.
9		Dasometric: stock . Compulsory	Total volume per hectare, biomass per hectare, carbon storage per hectare,…	Calculus required	Calculate.	Stored in Cross-Forest dataset.
10		Mixture. Compulsory	Percentage of density and storage by species	Calculus required	Calculate.	Stored in Cross-Forest dataset.
11		Environmental: Climatic. Optional	Temperature, precipitation,… Can be included as input in growth equations	Depends on model requirements	Estimate and include for the species that need it.	Stored in Cross-Forest dataset.
12		Environmental: Soil. Optional	Physical or chemical characteristics,… Can be included as input in growth equations	Depends on model requirements	Estimate and include for the species that need it.	Stored in Cross-Forest dataset.
13		Environmental: Productivity. Compulsory	Site index or any other parameter aim to estimate the productivity of the area	Estimation required	Estimate. It depends on each species.	Stored in Cross-Forest dataset.
14	CAMBRIC – Models Definition	Productivity equations	Site index equation	Species dependent. It is necessary to calculate at the start of each scenario.	Write script to calculate when necessary.	Script available to use in scenarios.
15		Growth equations	Size rate change	Species dependent. Is necessary to calculate at several nodes of each scenario.	Write script to calculate when necessary.	Script available to use in scenarios.
16		Size Variables relationships	Allow size variables calculus based on basic size variables (usually diameter). Necessary for estimate size variables used as input in growth equations	Species dependent. Is necessary to calculate at several nodes of each scenario.	Write script to calculate when necessary.	Script available to use in scenarios.

Requirements	Use Case	Short Title	Description/Motivation	Pre-condition	Normal sequence steps / actions	Postcondition
17		Ingrowth equations	For estimate new tree appeared in a period of time	Species dependent. Is necessary to calculate at several nodes of each scenario.	Write script to calculate when necessary.	Script available to use in scenarios.
18		Mortality equations	For estimate dead trees in a period of time	Species dependent. Is necessary to calculate at several nodes of each scenario.	Write script to calculate when necessary.	Script available to use in scenarios.
19		Taper equations	Will allow wood volume calculation	Species dependent. Is necessary to calculate at several nodes of each scenario.	Write script to calculate when necessary.	Script available to use in scenarios.
20		Dasometric equations	Basic variables equations: basal area, quadratic mean diameter, …	Calculus required. Is necessary to calculate at several nodes of each scenario.	Write script to calculate when necessary.	Script available to use in scenarios.
21-1	CAMBRIC – Industry Requirements	Dimensions and quality requirements by end uses. Calculate the amount of wood available for each end-use and geographic area	Veneer	species dependent	Write a script for each species/group to calculate volume of suitable minimum and maximum diameter for it end-use.	Script available to use in scenarios.
21-2			Wood for saw big			
21-3			Wood for saw small			
21-4			Wood for saw canter			
21-5			Wooden post			
21-6			Wood stake			
21-7			Chips			
22	CAMBRIC – Simulation Definition	Passive: Unmanaged forest nature reserve	Scenario definition. No selvicultural treatments, only stand development	Species independent.	Write a script to perform scenario.	Set of scripts adequate to perform scenarios for pure *Pinus sylvestris*
23		Low: Close-to nature forestry	Scenario definition.	species dependent	Write a script for each species/group to perform scenario.	
24		Medium: Combined objective forestry	Scenario definition.	species dependent		
25		High: Intensive even-aged forestry	Scenario definition.	species dependent		

Requirements	Use Case	Short Title	Description/Motivation	Pre-condition	Normal sequence steps / actions	Postcondition
26-1	CAMBRIC – Data preparation	Data selection: Pinus sylvestris (Psy) pure	Selection of patches of the Spanish Forest Map for each species/group and selection of the included plots of the Spanish National Forest Inventory	Data stored in several files and tables, separated by administrative Provinces.	Store all data in open linked data to allow easy access. Write necessary queries for data selection	Subset for each species/group available in Virtuoso to perform simulations
27-1	CAMBRIC – Simulation	Simulations: Pinus sylvestris (Psy) pure	Perform of simulations of scenario 21-24	Knowledge about current wood quality situation of forest stands in Spain	Run adequate simulation to each set of data (species/group)	Knowledge about current wood quality situation of forest stands stored in virtuoso and possible evolution depending on applied silviculture

Annex II CAMBRIC external datasets, general table

Themes	Variables	Access mechanism	Data required	Data gathering	Data format	Requirements Related with this source of data
Tree and stand level inventory data	Tree species					Accesible LOD
	Tree age				SPARQL	Accesible LOD
	Tree relative position in the plot				SPARQL	Accesible LOD
	Dendrometric: Tree size				SPARQL	Accesible LOD
	Plot absolute position				SPARQL	Accesible LOD
	Dasometric: plot density				SPARQL	Accesible LOD
Spatial occupation of territory	Patch strata and species composition	Sparql endpoint			SPARQL	Accesible LOD

Annex III CAMBRIC data transformation, general table

Questions	File/Database required	Processing rules	Publicar como LOD Yes/No
What are current wood quality at plot level?	Spanish NFI	Direct Simanfor output	Yes
What are current wood quality at patch/stratum level?	Spanish Forest Map	Statistical transformation from plot to stratum	Yes
How affect sivicultural scenario to wood quality evolution?	Spanish NFI and Forest Map	Direct Simanfor output and statistical transformation	Yes

Annex IV FRAME requirements, general table

Requirements	Use Case*	Short Title	Description/Motivation	Pre-condition	Normal sequence steps/actions	Postcondition	Iteration 1 (M18: feb2020)	Iteration 1/2 (M25: sep2020)	Iteration 2 (M30: feb2021)
0	FRAME (Stage I)	Cell matrix definition	User defines cells matrix in order to be filled with data during next steps	Tile definition	User defines cell matrix: corner coordinates, cell size and quantity	Cell matrix defined for simulation in Stage I	x		
1	FRAME (Stage I)	Fire starts: points and/or perimeter ignition	User defines points of initial ignition in order to be used in simulation	Defined cell matrix is loaded	User defines ignition points in cell matrix	Ignition points sending to propagation core	x		
2	FRAME (Stage I)	Located Area Data Loading: DEM	Propagation core needs terrain height data for simulation, assigned in this stage for the area defined by cell matrix	Local data input origin from predefined scenario	Propagation core loads terrain height data	Terrain, roads and infrastructures, meteo and fuel models data are assigned to each cell in matrix	x		
3	FRAME (Stage I)	Located Area Data Loading: roads and infrastructures	Propagation core needs infrastructures data for simulation, assigned in this stage for the area defined by cell matrix	Local data input origin from predefined scenario	Propagation core loads infrastructures data (roads, trails, firebreaks, edification...)		x		
4	FRAME (Stage I)	Located Area Data Loading: meteo data	Propagation core needs meteo data for simulation, assigned in this stage for the area defined by cell matrix	Local data input origin from predefined scenario	Propagation core loads meteo data (air temperature, wind spread and direction, relative air humidity)		x		
5	FRAME (Stage I)	Located Area Data Loading: fuel models	Propagation core needs fuel data for simulation, assigned in this stage for the area defined by cell matrix	Local data input origin from predefined scenario	Propagation core loads fuel model data (variables defined in propagation core)		x		

6	FRAME (Stage I)	HPC Computing	Propagation core runs with alternative parameters over HPC Calendula of Scayle in order to demonstrate the parallelism capacities	Cell matrix, input data and ignition points loaded on HPC	Propagation core runs on HPC Calendula	Active cells by time output files	x		
7	FRAME (Stage II)	Mapping of fire perimeters in Emercarto	Output from HPC Calendula is converted to perimeter polygon layer and showed in wildfire management system EMERCARTO	Output results from simulation executed in HPC Calendula: fire perimeters	Calendula output files are vectorised in fire polygons suitable to EMERCARTO	Visualization of fire polygons in EMERCARTO (perimeters layer)		x	
8	FRAME (Stage II)	Extensive Data Loading: DEM	System incorporates topographical (Digital Elevation Model) data available from open resources by public administrations in Spain and Portugal	Updated links to DEM information	Loading data from local/online sources in an specific surface and propagation core running in HPC Calendula	Updated terrain, roads and infrastructures, meteo and fuel models data and fire perimeters		x	
9	FRAME (Stage II)	Extensive Data Loading: roads and infrastructures	System incorporates infrastructures data available from open resources by public administrations in Spain and Portugal	Fuel model data to overwrite and link to infrastructure information				x	
10	FRAME (Stage II)	Online Data Loading: meteo data	System incorporates meteo data (prediction/historical) from online resources by public administrations	Online connection to meteo data providers (AEMET and others)				x	
11	FRAME (Stage II)	Extensive Data Loading: fuel models from Spanish Forestry Map CrossForest LOD	System incorporates fuel data available from open resources by public administrations in Spain and Portugal	Connection to Spanish Forestry Map Linked Open Data provided at CrossForest endpoint				x	
12	FRAME (Stage II)	Extensive Data Loading: fuel models from Autonomous Communities	System incorporates fuel data avalaible from open resources by regional administrations in Spain	Fuel data availability for some regional areas				x	

13	FRAME (Stage III)	EMERCARTO connection: fire start points or perimeter	Provide EMERCARTO with edition tools which captures and sends ignition points to FRAME propagation system	Creation of EMERCARTO edition tools	Fire ignition points or perimeters are drawn in EMERCARTO and simulation is started	FRAME calculates propagation and returns fire perimeters to EMERCARTO			x
14	FRAME (Stage III)	EMERCARTO connection: combat actions	Provide EMERCARTO with edition tools which captures and sends combat actions in real time to FRAME propagation system	EMERCARTO-Calendula communication: visualization of fire perimeters in EMERCARTO	Combat actions in real time are drawn in EMERCARTO and simulation is recomputed	FRAME updates propagation and returns fire perimeters to EMERCARTO			x

Annex V FRAME external datasets, general table

Themes	Variables	Data sources	Access mechanism
		Spain	
DEM (digital elevation model)	Individual defined cell height	http://centrodedescargas.cnig.es/CentroDescargas/index.jsp	web download
		Regional cartogtaphy services	Undefined
Forestry map (fuel layer)	W, H, Vp, Tool Integrity	Spanish National Forestry Map	web services
		Spanish National Forestry Inventory	web services
Meteo historic and realtime updates	T, RH, Wind direction, Wind spread	http://www.aemet.es/es/datos_abiertos/AEMET_OpenData	API REST
		Regional meteo systems	Undefined
Roads and infrastructures	Individual defined cell assigment	http://centrodedescargas.cnig.es/CentroDescargas/index.jsp	web download
		Regional cartogtaphy services	Undefined
		https://eurogeographics.org/products-and-services/open-data/topographic-data/	web download

Annex VI FRAME data transformation, general table

Questions	File/Database required	Processing rules
What will be fire perimeter at the hour "x"?	FRAME cells status	Active cells
Will fire reach an specific point? At which hour?	FRAME cells status	Will the cell reach active state and at wich moment?
What will be flame lenght or fire intensity at an specific point and hour?	FRAME cells status	Intensity value of cell at a certain place and at any given time
What will be rate of spread at an specific point and hour?	FRAME cells status	Rate of spread value of cell at a certain place and at any given time
Will fire exceed track or barrier, "x" meters wide, in his predicted progress?	FRAME cells status	Intersection between selected firebreak and fire perimeter of active cells
Such a municipality will be affected? Such a natural space? In which proportion?	FRAME cells status/ EMERCARTO DB	Intersection of EMERCARTO layers with active and burned cells
Wich roads or paths will intersect the predicted progress of fire?	FRAME cells status	Touch of roads or paths cells with active and burned cells
What will be the affected surface at an specific moment?	FRAME cells status	Total amount of burned cells
What will be maximun registered fire intensity and rate of spread? At what points?	FRAME cells status	Cells with highest I or Vp
Wind direction or slope at a certain place and at any given time?	FRAME cells status	Cell slope and wind direction values
What's the type of vegetation at a certain place and at any given time? What percentage of burned area, according to the type of vegetation, will be affected in each case?	FRAME cells status/ EMERCARTO DB	Intersection of EMERCARTO layers with active and burned cells
Within an active perimeter at a given time, which is the most active point, that is, with higher rate of spread or fire intensity?	FRAME cells status	Highest I or Vp in active cells

