EFDM country test report

France

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Contents

1. Introduction

In the French case study, we (i) produced the inputs for running the EFDM software and (ii) carried out a comparison with the results calculated with the national age class model.

The French forest presents a high diversity in terms of tree species and stand structure (Morneau et al. 2008, Colin et al. 2014b). It results from both ecological (climate, soils) and socio-economic factors (physical and environmental constraints on forest accessibility, ownership categories and forest owners objectives, etc.), and their changes in time.
Indeed, since the beginning of the 19th century the forest area has doubled in France, mainly from of natural afforestation on abandoned agricultural lands. In 2010, coniferous stands cover 28 % of the national forest area (in violet on fig. 1 below).

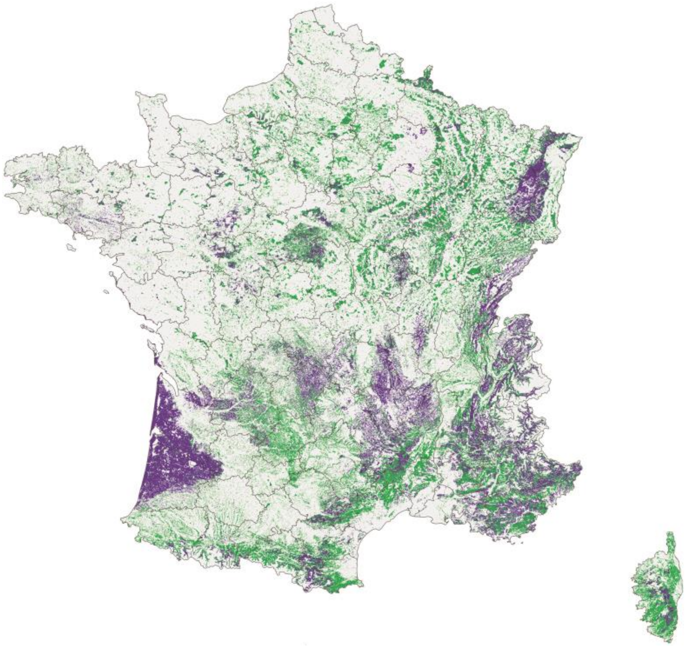

Fig. 1: map of broadleaved / coniferous stands in France (IGN)

The total growing stock in the French forest has also doubled over the last 50 years (IFN 2011), resulting from afforestation (including plantations of coniferous species after the 1950), changes in forest productivity (Charru et al. 2014), and the conversion of former coppices and coppice-with-standard stands to high forest stands. Thus, most of the forest stands in France are not evenaged.

As a consequence, two large-scale models are used in France (Colin 2014a) to model the forest resource and its evolution, depending on the type of forests to be simulated: an age-class model for evenaged stands and a diameter-class model for the others (Wernsdörfer et al. 2012). It allows tackling forest diversity, forest conditions and forestry development of a region when most of the tree species miss a specific growth model. This flexible modelling approach therefore delivers robust projections at short and medium time scales, and different spatial scales ranging from regional to national.

EFDM model in SC14 is dedicated to evenaged stands. Then, a subset of the total evenaged stands in France has been defined to test the model.

2. Model setup (EFDM)

2.1. NFI data

The French NFI consists in a repeated and spatially-systematic inventory of the French metropolitan forests to provide statistics at the regional and national levels (Robert et al. 2010, IGN 2014). Since 2005 the French NFI is continuous on an annual basis at national scale.

For the French case study, a dataset based on the NFI temporary plots inventoried from years 2005 to 2013 (9 annual surveys) was used to calculate the forest resource in 2009 (average year).

<u>Selection of evenaged stands</u>

Evenaged stands were identified within a **large region made of six NUT2 regions** (figure 2), located in northern France (Nord-Pas de Calais, Picardie, Ile-de-France, Champagne-Ardenne, Basse-Normandie and Haute-Normandie).

The area represents 1/5 of total France, and the forest cover is 18 % (1.82 Mha, including 1.77 Mha of forests available for wood supply), ranging from 28 % in Champagne-Ardenne till 8 % in Nord-pas de Calais. One third of the forests in the area are public owned. This area consists in flat lands, and it the climate is oceanic. The dominant species are pedunculate and sessile oaks, common beech, hornbeam and ashes for the deciduous species. There are few coniferous stands in the area (scots pines, black pines, spruce, silver fir and Douglas fir), and most of them were planted recently.

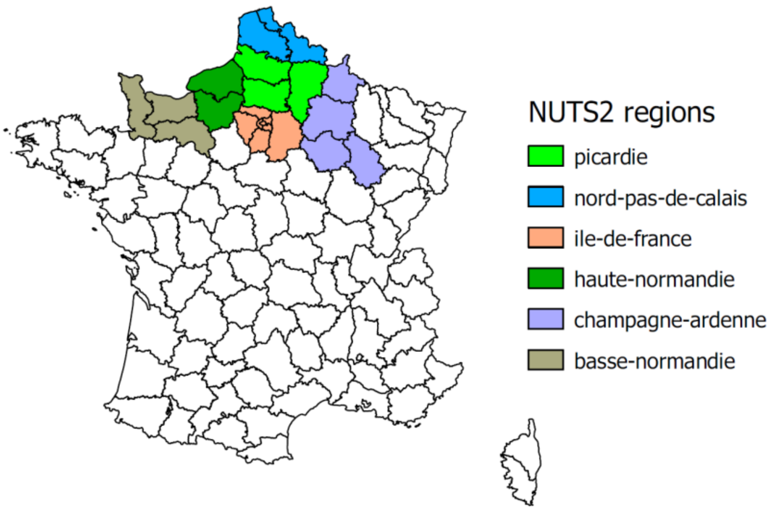

Fig. 2: map of administrative regions included in the case study

Three tree species groups were selected for the development of the case study, considering they were all suitable for an age-class model approach: oaks (group made of pedunculate and sessile oaks), beech and coniferous stands. All together the dataset includes 4,463 NFI plots (all temporary) which correspond to 1,016 Mha of forests.

2.2. State space

The model state space is based on the following dimensions (factors): volume (10), age (ranging from 17 to 37, depending on tree species), tree species (3) and ownership categories (2). The number in brackets indicates the number of classes (factor levels). Of all dimensions, only volume and age were dynamic. The distribution of forest area along other dimensions remains unchanged when the model is run. These define the forestry types. In the following paragraphs, we shortly describe each dimension, present the class definitions and describe the applied classification procedures.

Tree species

We defined **3 tree species composition classes**: oaks, beech, and coniferous dominated stands. NFI plots were sorted according to these types depending on the tree cover rate of these species (estimated on a maximum 25 meters radius plot, i.e. approx. 2000 m^2).

Ownership category

We defined **2 ownership classes**: private and public managed forests.

Public managed forests are state owned forests, forest of the local collectivities, and also forests belonging to public organizations. They are all managed by the same organization (ONF, for Office National des Forêts).

Tree species and ownership categories = forestry types

Dominant tree species	Ownership	NFI plots	Area (x 1000 ha)	Volume* (x 1000 m3)
OAK stands	priv	1,781	405	82,890
	pub	1,039	237	45,550
Total OAK stands		**2,820**	**642**	**128,440**
BEECH stands	priv	344	78	15,701
	pub	505	116	20,371
Total BEECH stands		**849**	**193**	**36,073**
CONIFEROUS stands	priv	525	119	25,619
	pub	269	62	14,546
Total CONIFEROUS stands		**794**	**181**	**40,165**
Total		**4,463**	**1 016**	**204,678**

** Volume definition: see below*

Volume classes

We defined **10 classes of volume per hectare**. The first class denoted by "1" is intended not only for stands but for bare land too. Bare lands areas are often supplied by some volume of living biodiversity trees which will be removed during the intermediate cuttings later. The limits for the classes 1 to 9 where defined according to the group of species. They are based on the volume distribution inventoried by the NFI teams, and also to some extent on the volume reported in the management "schoolbooks" for these species in this area, in order to be sensitive to thinnings.

Typically the volume estimate in the French NFI includes the stem volume of the living trees with a DBH above 7.5 cm, up to a top diameter of 7 cm. The volume is estimated over bark and from ground level.
For deciduous stands (oaks, beech), the class width is 40 m^3/ha, while it's 50 m^3/ha for coniferous stands. The length of the volume classes is constant. The last class (10th) has no upper limit.

Age classes

NFI plots are all temporary in France. On every NFI plot, the field team estimate whether some trees within the plot have been cut or not during the last 5 years. Thanks to such qualitative information, NFI plots can be split between no-management and cutting activities.

Age-classes have then a 5 years width. Howether, the total number of age-classes depends on the group of species. We defined:

- **37 age classes for oak stands**, starting from 0-4 years old (which includes bare lands) up to 180 years old.
- **31 age classes for beech stands**, starting from 0-4 years old up to 150 years old.
- **17 age classes for coniferous stands**, starting from 0-4 years old up to 80 years old.

The last class has no upper limit.

2.3. No-management transition probabilities

The state of NFI plots at 2 times is needed for the estimation of no-management transition probabilities (i.e. growth). However, the French dataset is made of temporary plots and we only have an estimate for the date T, which is the date of the forest inventory. Therefore, to obtain a standing volume estimate at time T-n, we subtracted from the current standing volume estimate the amount of growth estimated from tree cores. The French NFI measures the length of the last 5 cores, on all trees. This procedure was implemented only on the plots where no cut have been recorded over the last 5 years (no recent stumps on the plot). Finally we estimated the standing volume at date T-5, and we deducted the age 5 year prior, reducing the current age by 5.

We finally built a "pair-data" dataset (age1 age2 / vol1 vol2) based on our basic dataset. The estimation of no-management transition probabilities for every factor combination was carried out with the help of the function included in the EFDM package.

2.4. Activity probabilities – forest management specification

For the estimation of activity probabilities, we used the same NFI dataset where the information on the occurrence of a tree removal over the last 5 years is recorded (and whether it is a thinning or a clear cut).

Frequencies of thinnings and final fellings (share of NFI plots) were estimated in every age-class for every dominant tree species. According to these, data probability functions were elaborated. Some corrections were made afterwards due to the influence of non-clear final cuttings, which decreases the probability of final fellings. Other corrections were implemented, inspired from the management “schoolbooks” available for the species in the area. For example, final fellings in oak stands were supposed to start in 130 years old stands, and follow the trend given in fig. 3. Since SC14 is a case study for testing EFDM on a French dataset, the forest management scenarios were not discussed with the local forest managers, and they were not analysed into details.

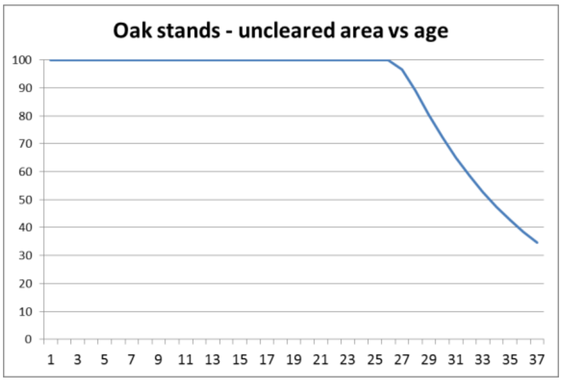

Fig. 3: evolution of the area of a given cohort with age (oak stand)

Finally, for each age-class of each tree species, we estimated the probabilities of the 3 different types of activities (fig. 4)

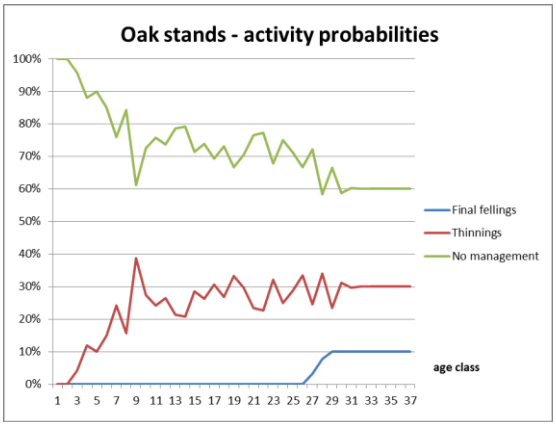

Fig. 4: activity probabilities with age (oak stands)

In the case study, thinning intensity was modelled as one volume class drop for every volume classes except the first one which correspond to little capitalised stands. Thinning probability is set to 0 for the first 2 age classes, corresponding to stands younger than 10 years old. The latter hypothesis was driven by the fact that the French NFI volume is measured only for the trees with a DBH larger than 7.5 cm.

Regarding regeneration, we assumed that all the clearcuts areas are immediatly back in the 1st age-class/volume-class.

2.5. Output variables

The basic form of any outputs is **forest area** in a certain class. This basic output can be expressed in terms of different variables by applying coefficients. We assumed that the forest area of each “forestry type” was constant over time.

The coefficients for deducing **volume** (growing stock) and **final felling** are direclty deduced from the volume class definitions. The average volume in the last volume-class is set to 1.20 * the upper limit of the class i-1, as proposed in the EFDM example.

The coefficients for **thinning volume** are deduced from volume class definitions and thinning definition (number of volume class drops).

The coefficients for expressing the basic outputs in terms of **total aboveground biomass** are produced by multiplying the above coefficients with specific biomass expansion factors (BEF). We applied the same approach as for the French green-house-gas inventory of the LULUCF sector.

In France aboveground biomass estimates are derived from volume estimates. The total aboveground biomass of a tree (stem, alive and dead branches, from ground level to top end diameter 0 cm, foliage excluded) is calculated in two steps:

- First, the total aboveground volume of the tree is estimated using total aboveground volume equations developed at national level (Vallet et al. 2006, Saint-André et al. in Loustau Ed. 2010). The total aboveground volume equations have been calibrated for the 7 most important tree species or group of tree species in France.
- Then, the total aboveground volume of the tree is converted into total aboveground biomass, using 33 tree species (or groups of tree species) infradensity wood factors derived from the scientific litterature available for France (Dupouey 2002, Dupouey et al. in Loustau Ed. 2010).

For each tree species group i we calculated the average BEFi (where BEF = total aboveground biomass / standing volume) on the NFI dataset. We obtained the following BEF: 0.855 for oak stands, 0.910 for beech stands, and 0.549 for coniferous stands.

The same approach is used for obtaining the coefficients for **sawlogs and pulpwood in the stem (includind fuelwood)**: thinning or final felling volume coefficients are multiplied by the coefficient describing the proportion of the given assortment for the given volume class. The same NFI dataset is used to obtain the coefficients for pulpwood and sawlogs, according to tree species and ownership classes. NFI field teams estimate the share of sawlog in the standing volume of each inventoried tree (fig. 5). We assumed the coefficients were different between public and proivate forests, considering public forests are managed more intensively. The assortment coefficients were applied to drain.

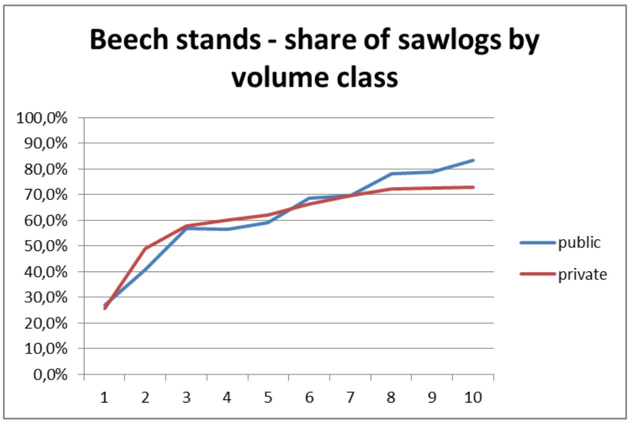

Fig.5: share of sawlog assortment by volume class (beech stands)

3. Results and comparison with national projections

For comparison with the EFDM results, we applied the national age-class matrix model developped and implemented in France for many years (the model is called OSCAR).

The French age-class model is a demographic model where each cohort (age-class) is represented by 3 variables (i) surface area, (ii) mean growing stock per hectare, and (iii) mean volume increment per hectare over a period. The French model relies on the following assumptions: i) the site and density conditions are constant over time within each age class; ii) the state of a cohort at the end of one time step only depends on its state at the beginning of that time step.

With the objective to evaluate EFDM, the national model was calibrated on exactly the same dataset as EFDM, and the same management assumptions were also implemented.

3.1. Results

The standing volume estimated with the 2 models start from the same initial point in 2009 (fig. 6). The mean growing stock per ha of the forests included in the case study area is 201 m^3/ha, which is significantly higher than the rest of France (160 m^3/ha).

This difference comes from the fact that most of the stands in the study area are high forests stands, while there are still many coppices with standards stands and former coppices stands in the rest of France. In addition, the stands included the case study domain are older and more mature than the French forest resource in general. The productivity in the domain is also higher.

Because the stands in the domain area are often close to the optimal age defined in the forest management standards for the corresponding species, the growing stock estimated with the two models don't change very much over time. However, the growing stock estimates rapidly differ for the 2 models: while the growing stock simulated with OSCAR is more or less constant, EFDM simulates an increase. Finally the growing stock estimated with EFDM is 6.5 % higher than OSCAR in 2029.

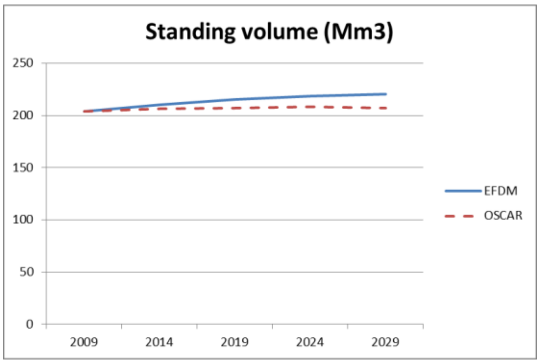

Fig. 6: projected standing volume calcultaed with the models EFDM and OSCAR

For each "forestry types", drains are estimated in the same manner by the two models, considering levels (quantities) and trends (fig. 7). Drains are increasing with time, as well as the share of sawlogs in total drains, in relation with the maturity of the stands.

The forest management scenario defined in the case study is mainly driven by observation data in the forest. Thus, the 2009 estimates are very close to the removals estimated directly from NFI field measurement (3.9 Mm^3/year +/- 0.6 Mm^3/year over the period 2005-2012). Actually, a specific wood removal inventory is carried out in France since 2010 indeed. It consists in an observation of the remaining trees of a set of NFI plots inventoried 5 years prior.

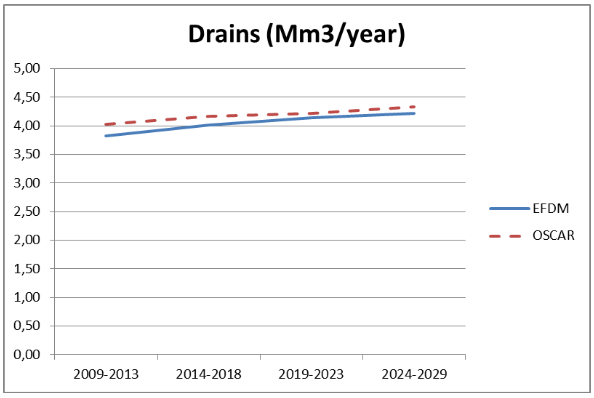

Fig. 7: projected drains calculated with the models EFDM and OSCAR

Table 1 shows the outputs calculated by EFDM and the comparisons with the national results.

Table 1: outputs from the French case study and the comparison of outputs with the OSCAR results

	year 2009	year 2014	year 2019	year 2024	year 2029	period 2009-2013	period 2014-2018	period 2019-2023	Period 2024-2028
Volume of growing stock									
EFDM, m^3*10^6	204	211	216	219	221				
EFDM, m^3/ha	201	207	212	215	217				
OSCAR, m^3*10^6	204	207	207	208	207				
OSCAR, m^3/ha	201	203	204	205	204				
Aboveground biomass									
EFDM, total $t*10^6$	163	169	173	176	178				
EFDM, t/ha	161	166	170	173	175				
Drains									
EFDM, total m^3*10^6/ year						3,82	4,01	4,14	4,22
EFDM, pulpwood m^3*10^6/ year						1,27	1,30	1,32	1,33
EFDM, sawlogs m^3*10^6/ year						2,56	2,71	2,82	2,89
OSCAR, total m^3*10^6/ year						4,03	4,16	4,23	4,33
Biomass of total drains									
EFDM, total $t*10^6$ /year						2,94	3,07	3,16	3,23
EFDM, t/ha/year						2,89	3,02	3,11	3,18
Growing stock incremen(1)									
EFDM, m^3*10^6/ year						5,2	5,0	4,8	4,6
EFDM, m^3/ year / ha						5,1	4,9	4,7	4,5
OSCAR, m^3*10^6/ year						4,6	4,3	4,4	4,1
OSCAR, m^3/ year / ha						4,5	4,2	4,4	4,0

(1) growing stock increment is calculated as the average “increment of growing stock” and “total drains” over the 5 years period, divided by the total area of the case study domain (1.016 Mha).

3.2. Discussion and conclusions

The objective of the case study was to test the enhanced features of EFDM in modelling the development of the growing stock and drains of evenaged forest stands in France. For this purpose, the EFDM model was set up on a NFI dataset representing 1 million hectares of evenaged forest stands located in northern France.

The results of the test shows that it is technically possible with EFDM to calculate output variables for evenaged stands, such as the volume of growing stock, its change over time, drains split by timber assortments, biomass of growing stock, and also growing stock increment.

Finally those results can be compared with the national results calculated with the national system / model for evenaged stands, which is also an age-class matrix model. The two models were calibrated exactly on the same NFI dataset, and the same forest management assumptions were also applied.

The model outputs are very comparable concerning total drains and their assortment between sawlogs and pulp and fuelwood. However, over the first 5-years period of simulation, the area assigned to clear-cut activity is underestimated by 10 % with EFDM compared to the national model. The difference reaches 15 % for the last age-class (EFDM modelling fewer clear-cuts than OSCAR). While the total gap decreases over time (EFDM is 6 % lower than OSCAR by the fourth 5-years period), the gap in the last age-class remains constant, with -15 % with EFDM.

More stands are then getting older in EFDM and the average age of the forest resource increases more rapidly with EFDM than OSCAR. Because the older stands have the higher growing stock per ha values, the model outputs on the volume of growing stock are diverging between the 2 models. The growing stock increases faster with EFDM than with the national model. It conduces to an overestimation of the volume increment compared to the national approach, and the carbon sink estimate too.

The 2 models are both based on an age-class approach. Nevertheless, the forest resource is not described exactly the same. EFDM relies on 2 matrices (volume-classes and age-classs) while OSCAR only relies on 1 age-class matrix and 2 vectors for each age-class, one for describing the mean volume/ha and one for describing the mean volume increment/ha. The national model then requires less parameters than EFDM, since the number of cells in the final matrix is lower.

A deeper analysis of the differences observed in the results between the 2 models should be developed in the future. The relative importance of the factors involved in the simulation could be analysed, for example to identify and quantify the specific effects of model calibration and model organization on growing stock evolution. Indeed, growth is not modelled the same in the 2 models, as well as growing stock estimate which is recalculated at the end of every simulation step in OSCAR.

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5. List of digital file annexes

Tree species	Characteristics	File name
Oak stands	Initial forest state	Initstate_oak.txt
	Probabilities of activities	Actprobs_oak.txt
	No management probabilities	Nomgmtdata_oak.RData
	Factors	Factors_oak.txt
	Activities	Activities_oak.txt
	Final fell probabilities	ffellP_oak.txt
	Thinning probabilities	thinP_oak.RData
Beech stands	Initial forest state	Initstate_beech.txt
	Probabilities of activities	Actprobs_beech.txt
	No management probabilities	Nomgmtdata_beech.RData
	Factors	Factors_beech.txt
	Activities	Activities_beech.txt
	Final fell probabilities	ffellP_beech.txt
	Thinning probabilities	thinP_beech.RData
Coniferous stands	Initial forest state	Initstate_conifers.txt
	Probabilities of activities	Actprobs_conifers.txt
	No management probabilities	Nomgmtdata_conifers.RData
	Factors	Factors_conifers.txt
	Activities	Activities_conifers.txt
	Final fell probabilities	ffellP_conifers.txt
	Thinning probabilities	thinP_ conifers.RData

6. Annexe A

Table A1: volume class limits

	Volume class									
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Oak stands	20	60	100	140	180	220	260	300	340	408
Beech stands	20	60	100	140	180	220	260	300	340	408
Coniferous stands	25	75	125	175	225	275	325	375	425	510