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Interactive comment on "The European forest sector: past and future carbon budget and fluxes under different management scenarios" *by* Roberto Pilli et al.

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Many thanks for this critical and constructive review.

Regarding your general comments on the language, we can certainly improve the text flow, including the captions and the longer sentences. The language will be revised as appropriate.

As highlighted by the Reviewer, the Carbon Budget Model (CBM) and the European Forest Information SCENario Model (EFISCEN) are quite similar, and, of course, we are not claiming that CBM outperforms, or it is better than, EFISCEN. The two models have some similarities and some differences, and for the needs of this study, we

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selected CBM-CFS3. Both these tools are inventory-based, yield-data driven models, using as main input National Forest Inventory data (Kurz et al., 2009; Schelhaas et al., 2016). Both models have been applied at local (e.g., Pilli et al., 2014 or Kujanpää et al., 2010), national (Stinson et al. 2011 or Forsström et al., 2012) and multi-national scales (Pilli et al., 2016 or Verkerk et al., 2014); both have been used to compare different scenarios, including changes in forest area, harvest demand, management strategies, etc. Both models distinguish the forest area by forest types (FTs) and age classes, eventually defined by administrative regions, owner classes, etc., and they require, for each FT, additional information on the average growing stock and increment (Kurz et al., 2009; Schelhaas et al., 2016). EFISCEN is basically a matrix model, where the transition between matrix-cells is driven by different processes, such as natural mortality and management regimes. For each five-year time step, a proportion of the area assigned to each cell moves up one age class. For each FT a basic, theoretical management regime of thinning and final cut, defines a "constraint" of what might be felled. As reported by Schelhaas et al. (2016), based on this theoretical management regime, the model searches and might find, depending on the state of the forest, the required harvest volume specified for each region, country and time step. The CBM is a dynamic simulation model that operates in annual time steps and can represent a wide range of forest management activities, land-use changes, and natural disturbances. It was originally developed and applied by the Canadian Forest Service mainly to even-aged forests (Kurz et al., 2009), but since 2012, the original modelling framework was successfully adapted, and tested in European systems including uneven-aged forests and other management systems, such as shelterwood or coppice (Pilli et al., 2013). One of the main strengths of the CBM is its flexibility in representing almost any possible management system. In the CBM, each disturbance type is controlled through a wide variety of criteria, including spatial and stand characteristics, age, amount of biomass and dead organic matter (DOM) in individual pools, stand history, etc. The impact of each disturbance is further defined using a matrix that describes the proportion of C transferred between pools (i.e., from living biomass to DOM), to the atmosphere (i.e., due to burning of forest residues) and to the forest product sector (i.e., harvest removals). Overall, this integrating framework allows, theoretically, to simulate the effect of any possible management system or natural disturbance event, such as windstorms, fires, insect attacks, etc. This is, in our opinion, one of the main strengths of the CBM and was among the reasons why we selected this very flexible modelling framework.

As highlighted, our purpose is to apply the same tool and model framework, to 26 different countries. This was also proposed by many authors using the EFISCEN model, but, as known, due to a long silvicultural tradition, the European forests largely differ not only with regard to the forest structure (i.e., species composition and age structure, considered by both these models), but also with regard to the specific managed practices applied at the country level. For this reason, we selected a very flexible tool, that allows us to model a wide variety of management practices and that accommodates a range of input data requirements. Based on the available country-specific information, the model can be run using a unique age class distribution, associated with an average value of volume and increment, without any further distinction between FTs. Alternatively, when additional information is available, it is possible to apply a very detailed analysis, at the regional or country level, further distinguished by FTs, management strategies, ecological regions, etc. Finally, the model can simulate the effect of different natural disturbance events, from fires, typically affecting the Mediterranean countries, to windstorm, mainly affecting central and north European countries, and the subsequent management responses, such as salvage logging. All these elements were implemented within a unique model framework, providing, at the same time, a consistent and complete output, including the annual estimates of C stocks and stock changes for each forest pool. Many of these aspects were also considered by other studies using the EFISCEN model, but in some cases, they focused on the effect of natural disturbances (i.e., Seidl et al., 2014), in other cases on different management practices (even accounting for the effect of climate-change on productivity, but always considering an even-aged sylvicultural system, such as in Schelhaas et al., 2015) or on other additional aspects not (yet) considered by our model framework, such as the maximum potential amount of harvest (Verkerk et al., 2011) or the forest ecosystem services (Verkerk et al., 2014). In summary, the CBM is a useful, but certainly not exclusive, tool to analyze the forest C dynamics, under different spatial scales and management scenarios. At the same time, using and comparing the results provided by different models, can represent an added value, to improve the confidence in model results, in particular when dealing with projections of the future C sink (Böttcher et al., 2012). A future study aimed at comparing these models, at least at the country level, would further improve our knowledge.

Your question, on the relationship between forest practices and physical/biological system is certainly very interesting, and we could, theoretically, analyze also this issue. In fact, we could use the ecological zones (as considered, for example, by Metzger et al., 2012) rather than the administrative (country) boundaries to summarize the results. A similar approach was already proposed by Stinson et al. (2011) for Canada and by Mascorro et al. (2015) for the Yucatan Peninsula, in Mexico. In these cases, the model stratification was done by both country boundaries and ecological boundaries. In our case, maps of temperature and precipitation classes were projected over a CORINE map and over the European administrative units, following the approach of Pilli, 2012. The resulting combinations of precipitation and mean temperature values were used to define 60 climatic land units (CLUs, as reported in Pilli, 2012, see Figure 1). For each country, the proportion of NFI forest area associated with each CLU, was estimated on the basis of CORINE data. Through this approach, even if our modelling framework was not spatially-explicit, we linked the forest area reported for each country to specific CLUs, associated with values of mean annual temperature and total annual precipitation (the CLU's mean annual temperatures, range from -7.5 to +17.5°). Because in CBM the decomposition rate for each DOM pool is modelled using a temperature-dependent decay rate (Kurz et al., 2009), also in our model framework the decay rate is modified according to the mean annual temperature of each spatial unit. The CBM also uses biomass turnover rates to represent mortality of biomass and litterfall rates and the transfer of dead biomass to DOM pools. Unfortunately, due to the lack of studies, we could not (yet) define these parameters at regional level, and extensively compare our results with other field measurements. This will be part of future model evaluations.

Specific comments: 1. L. 89, yes, you are correct, biogeochemical will be substituted with biophysical, as suggested. 2. L. 270, yes, here we refer to a model-model comparison, and as you say, the turnover time of each wood commodity (i.e., sawnwoods, wood based panels and paper and paper board) cannot be measured precisely. We based our estimates on the default values reported by the Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol, 2013 (IPCC, 2014). We can highlight this uncertainty, as suggested by the reviewer. 3. L. 376 – 381: Yes, we can further develop this sentence. In particular, if we assume that the biomass removed from deforested areas (i.e., about 5 Tg C yr-1) would be entirely used as fuelwood (FW) or industrial roundwood (IRW), this would reduce the amount of living biomass removed through other management practices (see Fig. 1 on the manuscript, arrows (E), (F), (G)). This would slightly increase the living biomass C stock and, as a consequence, the NBP of the FM area, but it would not affect the direct emissions due to FW and to the decay process affecting IRW, since the absolute amount of FW and IRW would not change. Excluding the effect of the natural turnover rate on the living biomass, the average living biomass (excluding leaves) could, potentially, increase from 7228 Tg C (see Tab 1S) to 7,233 Tg C (i.e., + 0.07% yr-1). 4. L. 481, we will delete the reference to “SAS®” and instead explain that the statistical analysis was performed through the “Proc Reg” procedure, using the R2 selection method to identify the model with the largest R2 for each number of variables considered. 5. L. 585 – 589: yes, you are correct, that the yield curves in the model are based on observations, and thus some impacts of environmental changes are represented in the model. However, many yield curves are based on plot measurements over the past decades we therefore cannot make any assumptions about how representative the existing yield curves will be for future environmental conditions. In the absence of environmentally-sensitive yield curves this is the best we (and the entire forest planning community) can do. 6. L.

597: yes, you are correct, ORCHIDEE is a process-oriented model, like JULES. The sentence will be correct.

Additional references:

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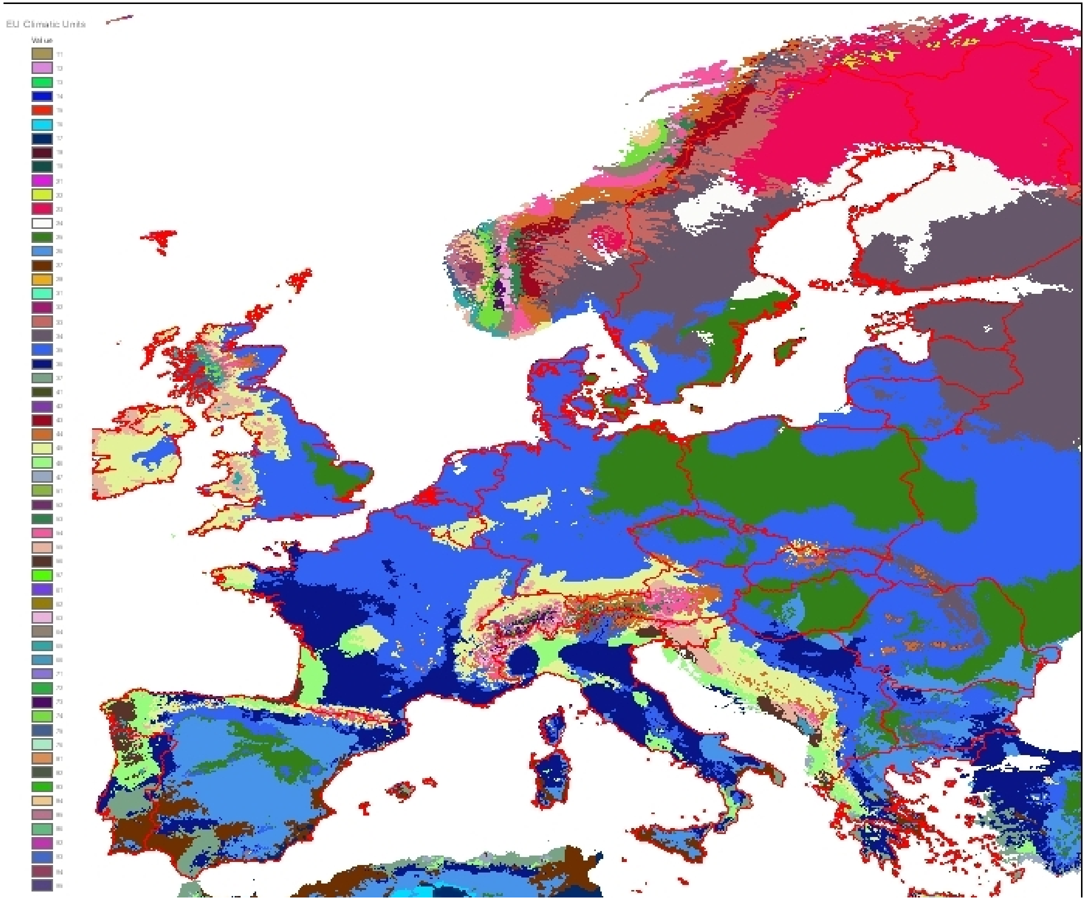

Fig. 1. : overview of the climatic units (CLUS) defined at European level and used to set the mean annual temperature applied by model.