Reviewer #2

Le Page et al. made some (simple) improvements in the prognostic fire model HESFIRE followed by parameter optimization. After the model is properly evaluated, they used it to predict future patterns of understory fires in Amazon forests under the CMIP5 RCP4.5 and RCP 8.5 scenarios. They found that land use change and climate change have a synergic role in strengthening fire activities in the RCP 8.5 scenario, with climate change exerting a dominant role, while conservative land use change under the RCP 4.5 scenario can actually mitigate fire occurrences. They also show that fire sizes will largely increase under both scenarios. It is already known from previous studies that degradation fires (though not all of them are understory fires) in Amazon forests are largely controlled by drought conditions in relation to climate variations (Malhi et al., 2009, PNAS), and land fragmentation and logging tend to increase the flammability of forests (Malhi et al., 2008 Science, Nepstad et al., 1999 Nature). Morton et al. (2008, GCB) shows that fire is an important agent in active management of agricultural lands after deforestation, for both pasture and croplands. In Morton et al. (2013) it is further shown understory fires are highly linked with deforestation frontiers (which is essentially land use change) and respond strongly to dry climate years or in general, to dry climate conditions. So in view of these studies, the conclusions in the current manuscript are not really very novel. But I recommend it being considered for publication for two reasons: (1) it incorporates the understory fires that are often neglected in global fire models. (2) it can provide useful insights for the future mitigation strategies for Amazon forests.

Some general comments:
My general comments mainly concern with improving the presentation, especially to be more precise in the texts. I find that the introduction section is written in a too much general and somewhat "loose" manner. For example, page 2, line 1-2 could be expanded to give more details. Descriptions in Page 2, line 23–26 is also too general, expressions like "predictable patterns of drought and fire risk form the basis of regional early-warming systems" could essentially apply on other fire types as well (e.g., boreal fires).
The flow of texts, to my point of view, sometimes lacks the necessary rigour needed in scientific writing. For example, page 2, line 24, "under a changing climate": although readers could guess from the contexts that the authors imply global warming or climate change, or more specifically, climate change that induces more frequent drought, I still think it's better the authors directly write it out precisely as they intend to mean. Some other examples include: page 2 line 34, "under novel climate and land use conditions", what do you mean by "novel" here?

We appreciate the suggestions to clarify the text. We have carefully edited the manuscript to avoid confusion with both general concepts and specific references to previous research on fire activity in Amazonia.

Page 3 line 12, "...while addressing their respective issues...", what are these respective issues?

The specific issues include vegetation error propagation in DGVM-fire models, and the 1-day limit imposed for fire duration, while multi-day fires are an essential aspect of understory fires. This has been clarified in the text:

P.xx, l.xx: "HESFIRE is a fire model of intermediate complexity seeking to combine the explicit fire representation in dynamic global vegetation models (DGVM-fire models)

with the performance of statistical fire models, while addressing some of their issues (Le Page et al., 2015). In particular, land cover distribution in HESFIRE is inferred from contemporary observations, avoiding error propagation from the vegetation scheme to the fire module, which is a recurrent challenge in DGVM-fire models (Kelley et al., 2013; Kelley and Harrison, 2014; Wu et al., 2015). HESFIRE was also designed to represent multi-day fires, tracking each individual fire on a 12-hour time steps, whereas other global fire models have a maximum fire duration of 1 day (Arora and Boer, 2005; Li et al., 2012; Thonicke et al., 2010). The model has been applied at global scale (Le Page et al., 2015) and used in a sensitivity experiment to evaluate the propagation of uncertainties from land cover and climate input data to estimates of fire activity (Le Page, 2016). The HESFIRE model was designed to facilitate the development of regional versions – a capability used in leveraged in this Amazon-scale study - with the integration of a data assimilation component to regionally adjust the parameterization of fire drivers based on observed fire dynamics."

Page 4 line 10, "...MODIS patterns appeared more consistent with the contemporary distribution of land use...", how such a conclusion is reached?

There are large regional-scale discrepancies in land use density between the MODIS and GLOBcover products (see figure 18.2a,c in (Le Page, 2016)). We chose MODIS based on expert knowledge in the team, and on a visual comparison of both datasets to other sources of information/knowledge on the regional distribution of land cover, especially agriculture (e.g. (Soares-Filho et al., 2014)). We now mention in the text:

P.xx, l.xx: "Although there is no comparison study of both datasets in the Amazon, MODIS patterns appear more consistent with the contemporary distribution of land use, as inferred from expert knowledge in the team and from a comparison with other sources of information (e.g. (Soares-Filho et al., 2014))."

The background of the current study is relatively well described, but I have a sense that it lacks a specific context that allow readers appreciating and better understanding the current study. For example, how about previous works by Alencar et al. 2004 (Ecological Applications) and Silvestrini et al. 2011 (Ecological Applications)? What are the progresses of the study in comparison to previous studies like these? The authors can also think to enhance the specificity in the discussion section as well.

We clarified in the introduction the novelty of the study for understory fires in the Amazon (P.2 l.27): "Projections of Amazon fire activity also suggest strong synergies between climate change and anthropogenic expansion scenarios (Cardoso et al., 2003; Le Page et al., 2010; Silvestrini et al., 2011), but previous work focuses primarily on deforestation and agricultural burning. **These fires are managed, burn different types of fuels, and are generally of short duration, thus provide few insights about the ecology of slow-moving, multi-day understory fires.** Understory fires are difficult to detect using satellite data because they do not burn the forest canopy, and only a few studies have inferred their extent in small regions to explore their dynamics and drivers (Alencar et al., 2006, 2004; Ray et al., 2005). However, a method was recently developed to detect understory forest fires using multi-year satellite image time series (Morton et al., 2011, 2013). These Amazon-wide observations provide a critical foundation to develop simulations of understory fire dynamics under novel climate and land use scenarios."

Minor comments:
Page 4 line 15: in this equation, what are terms originally included in the HESFIRE in Le Page et al. (2015)? What are the new terms added accounting for understory fires?

The whole equation is new, as fire ellipses were fully burned in the original version of the model (BA = E). We have now clarified this in the text:

P.4 l.18: "A new equation was developed in this study to compute the area that actually burns as a fraction of the plain ellipse, driven by landscape fragmentation and fire weather:"

$$\boldsymbol{BA = E \times \left(1 - {F_n}^{F_{exp}}\right) \times \left(1 - RH_n^{RH_{exp}}\right) \times \left(1 - SW_n^{SW_{exp}}\right) \times \left(1 - T_n^{T_{exp}}\right)}$$

In section 3.1, could you explain how a better agreement between model and data is achieved? Is the inclusion of the extra term (land fragmentation impact on fire size) critical, or a recalibration of the original parameters more critical?(The authors could give some words based on their experts on their model, not necessarily with new simulations). I have a feeling like the interannual variability of the original model result is OK but just its magnitude is too high (Figure S2), so that an extra term is needed to bring down the burned area.

As clarified in the previous section, equation (2) was entirely new in the model: fire size was affected not only by land fragmentation, but also by fire weather.
We did runs with 3 configurations of the model to explore the impact of the new fire size equation and of the regional parameterization (see Figure R1 below). When only the fire size equation is appended to the original model, burned areas are clearly lower and more realistic, and inter-annual variability is also improved (e.g. the 2005 peak is reduced). When the parameters were re-optimized, both burned areas (e.g. 1999, 2001-2002) and inter-annual variability were also affected, although not as much.

We now cite this discussion in the paper: "The regional version of HESFIRE reproduced the observed spatial patterns of average fire activity, including the clear boundary between fire-affected forests along the arc of deforestation and mostly fire-free forests in more humid regions of the central and western Amazon with less agricultural activity (Figure 2a, Figure S2, see also reply to referee comment #2 about the contribution of model adjustments to improved performances*)."

* All interactive comments in ESDD are fully citable. Citation format to be modified according to the journal standards.

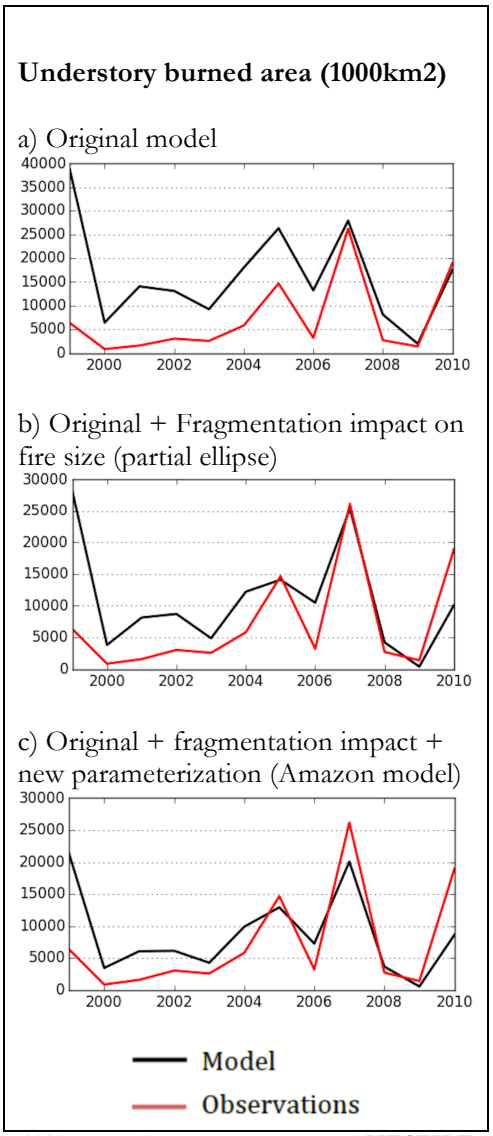
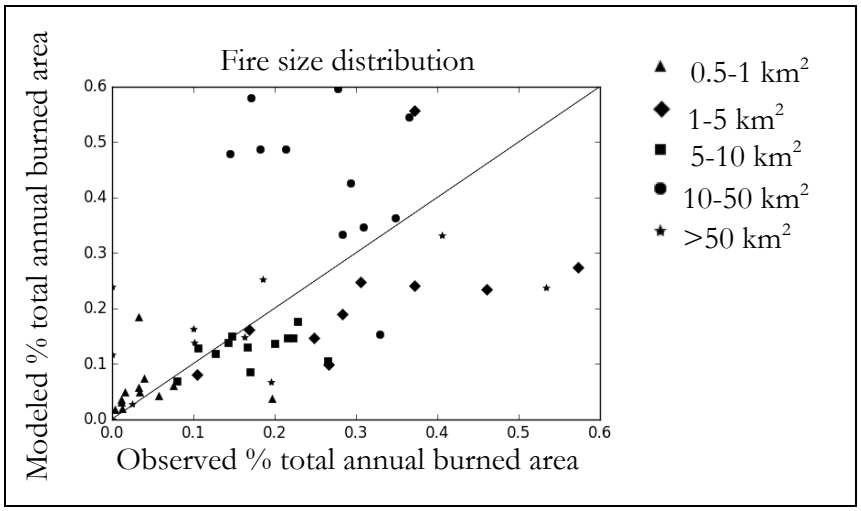


Figure R1: 1999-2010 annual burned areas under 3 HESFIRE configurations.

Visually looking Figure 2(c) is quite OK but could you show a scatter plot (model versus observation) as well (maybe in the supplement)?

We have generated an alternate version of Figure 2 (panels b and c).



We added the figure in supplementary material if readers want to get a closer look on this aspect. We maintained the short discussion in the paper unchanged ("fire size distribution consistent with observations").

Finally, how the land fragmentation is measured in the model? Like you used some land cover map derived index?
Yes, the fragmentation in a grid-cell index is calculated as the fraction of land covers that represent a significant barrier to fire propagation. We have now clarified this information in the model overview section:

(P.4, l.5): "- *Fire termination*. Four factors control the termination of fires: a) a change to non fire-prone weather conditions (e.g. fires terminate when relative humidity increases above 80%); b) low fuel availability (the probability of termination is higher in sparsely-vegetated landscapes); c) landscape fragmentation (**the fraction of a grid-cell covered by croplands, urban areas, water bodies, bare areas, and burned areas over the last 8 months);** and d) fire suppression efforts, which intensify with higher land use density and GDP, but become less efficient under increasingly fire-prone weather."

Figure 3 and the associated results: Are these percentiles calculated by pooling on over each grid cell the results from different climate models? Is there a risk that the fires could be overestimated because different climate models give different spatial patterns of drying (Fig 1 B)? I mean, spatially we pick up the 90th percentile over each pixel so that the spatial total of the 90th percentile fires are much larger than, if we just pick up the 90th of total fire impacted areas from different models, because models compensate for each other spatially?

The reviewer is correct in that Figure 3 shows the gridcell-level percentiles among different climate models. As such, none of them is a regional-scale output of one given model/scenario. We feel it gives a better representation of the ensemble runs. Picking one model run that results in a 90th percentile of region cumulative burned areas, for example, would focus the results/discussion on the area most heavily impacted by that given climate model projections. Other areas would be seemingly resilient to climate change, but it would appear this way only due to that specific model.

Given that we also show the 10th percentile and median, we believe this gives an adequate view of fire projections among the ensemble runs. Regional-scale burned areas for each

model/scenarios are shown in Figure S5. We have clarified the underlying method in the caption of figure 3:

New caption: "Figure 3: Annual burned fraction projected in HESFIRE for 2080-2100 varies across models and climate scenarios. The 10th, 50th and 90th percentiles are **calculated at the grid-cell level among the 8 climate runs** (see Methods)."