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Interactive comment on "Understanding the effect of fire on vegetation composition and gross primary production in a semi-arid shrubland ecosystem using the Ecosystem Demography (EDv2.2) model" *by* Karun Pandit et al.

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Response to interactive comment on "Understanding the effect of fire on vegetation composition and gross primary production in a semi-arid shrubland ecosystem using the Ecosystem Demography (EDv2.2) model" by Karun Pandit et al.

Reviewer 1

Overview:

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Discussion paper

This study uses a dynamic vegetation model to quantify the impact of fire on GPP in a shrub community. The model is somewhat able to represent observed patterns in vegetation and GPP dynamics after fire. However, I find the manuscript to be somewhat immature, with pieces of the methods section in the introduction, unsatisfying basic description of model parts which are relevant for this study, missing information in figures etc. and especially a lack of a clear science question or hypotheses to be tested. While I agree that it is worthwhile to improve shrub representation in DGVMs and how these interact with fire, I don't have the feeling the present study takes advantage of the DGVM to ask questions beyond what is known regarding basic impact of fire on sagebrush communities.

Thank you for the comments. We will move the model description from the introduction to methods, rephrase our objective, and clearly state our hypothesis to provide clarity. We will also provide clarity on figures.

We agree there is more work to be done to understand fire in sagebrush communities with EDv2.2 and other DGVMs. However, there is a knowledge gap in understanding the uncertainties of EDv2.2 in assessing the impact of fire on shrub dominated semi-arid ecosystems like the Great Basin region. The aim of this study is to document the potential usefulness and errors in modeling fire behavior with EDv2.2 as a first step in further developing the model for shrublands. Findings from this study has a potential to contribute to substantial utility beyond academic exercise to track shrubland carbon and productivity dynamics at broader scales, as sagebrush is found throughout Western United States and Southwest Canada. Results from our study would also be valuable given this widespread ecosystem is threatened by fire and invasive grasses. Our study could be a preliminary step in that process, to make EDv2.2 a model that can address global changes via dynamics in semiarid shrublands.

We will revise our related sections and include required references to emphasize the importance of this study. In addition, we will add a sentence or two in the conclusion to re-emphasize these issues and the potential for EDv2.2 to address them with further PFT parameters and fire module refinement.

We will more precisely rewrite our science questions as:

a. What is the projected GPP of a sagebrush-steppe shrub PFT in the Ecosystem Demography (EDv2.2) model for two different fire disturbance scenarios compared against a no-fire scenario (control scenario)?

b. How are the spatial and temporal dynamics of fire disturbance and post-fire recovery represented in EDv2.2 in comparison to remotely sensed data??

Comments Line 51-71: why would you want to describe the model in this detail in the introduction? This section clearly needs to be moved to the methods. It also needs to be expanded so that one can get a basic idea what the model does, what the fire model does, what happens with the vegetation when a fire occurs etc.

Thank you for your comments. We will move some of the model description (that is not used as background/introduction) to the methods, and provide additional information on the fire module in a subsection of the Methods.

L72-78: Why are you only interested in the effect of fire on GPP, as this is probably the variable where you expect least change through time as vegetation generally is replaced or regrows. In the abstract you mention changes in fire frequency, but you don't follow up on this in your objectives and analysis performed. Probably changes in fire frequency might have an impact, possibly on (soil) carbon, or impact vegetation competition through feedback through the N-cycle, etc. To be clear, I don't say you have to do other analysis, but after reading the manuscript I still wonder why you focused on GPP and no on other aspects of the system which be as relevant.

We used GPP as it is often a direct output of process-based vegetation models. EDv2.2

calculates GPP based maximum photosynthesis using the Farquhar model (Farquhar et al.,1980). In addition, GPP estimates correspond well with remote sensing derived products like NDVI (normalized difference vegetation index), LAI (Leaf area index) and fAPAR (fraction of photosynthetically active radiation absorbed by the vegetation). While we limited our study to GPP, future studies could compare EDv2.2 outputs with remote sensing observations such as net ecosystem production (NEP), leaf area index (LAI), or above ground biomass (AGB). We compared two different levels of fire severity against control (no-fire) scenario at point levels to explore the dynamics of vegetation through the patterns in GPP. The EDv2.2 model could be simulated with alternate N effects including its effect on photosynthesis and decomposition. However, in this analysis we were not focused in the Nitrogen cycle.

L 83: Can you give the range in mean temperature and precipitation?

We will provide the range in the revised manuscript. Range of mean annual precipitation range from around 250 to 1100 mm and mean annual temperature ranges from about 5 to 10 °C.

L105: indicate which reanalysis data was used for downscaling using WRF.

We used "North American Regional Reanalysis" to downscale WRF data. We will add text and reference to make this clear in the revision (Reference given below).

Reference: National Centers for Environmental Prediction/National Weather Service/NOAA/U.S. Department of Commerce (2005), NCEP North American Regional Reanalysis (NARR), http://rda.ucar.edu/datasets/ds608.0/, Research Data Archive at the National Center for Atmospheric Research, Computational and Information Systems Laboratory, Boulder, Colo. (Updated monthly.) Accessed 01 Nov 2018.

L121: Does this mean you don't perform a spinup? How does this work with the N-cycle (which you seem to model, based on what you say in the introduction).

We used existing vegetation state with both shrub and C3 grass to initialize the point-based simulations. We ran the simulation for 25 years to get the vegetation and other ecosystem conditions such as Nitrogen and soil carbon. However, as suggested in this study we were not focused on assessing N-cycle.

L142: Trends doesn't seem to be the right term, temporal dynamics in GPP? There should exist some literature on vegetation dynamics after fire for these vegetation communities so that you can have an indication whether your simulations capture vegetation dynamics.

We agree to rephrase as temporal dynamics in GPP. There are a number of studies assessing GPP recovery and vegetation dynamics after fire. Such studies suggest change in ecosystem carbon exchange from source to sink after fire. These studies show considerable variability in the number of years required to return GPP to pre-fire conditions. Another threat to these ecosystems is that many do not recover and become dominated by exotic annual grass communities that are highly fire prone. We will cite studies which have focused on sagebrush-steppe post-fire recovery, as a comparison to our results. We would also highlight the need for further development of the C3 grass PFTs to better reflect annual grass dynamics in the conclusion section.

L156-157: You don't explain what the driver in the model for this lower GPP with increasing shrub cover is.

The main driver behind this dynamic of GPP for two PFTs can be described in terms of secondary succession and competition. In the initial years after fire, there are favorable growing conditions for grasses to grow quickly and produce high GPP. As shrubs start to recover, competition increases, shade is increased and belowground root completion is also higher. These factors reduce the growth of grass thus causing a net loss in total GPP, even with the increase in shrub GPP.

L163-164: why didn't you use actual reanalysis forcing so that you can compare interannual variability. Like that one could also assess model performance in figure 4.

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Discussion paper

We agree that it would be possible to assess model output by comparing results with EC towers if we used respective years of forcing data. However, as the primary intent of this study was to explore the temporal GPP dynamics for two PFTs with fire disturbance as the driving factor, we used an average annual meteorological forcing data and thus minimized interannual variability from weather data. In our previous study on model performance (Pandit et al., 2019), we had applied actual yearly forcing data to perform model validation.

L169-170: why? E.g. a fire will burn a shrub immediately, so why would GPP be lowest a couple of years after the fire. When reading this, one wants to know why this happens. Maybe put biomass and GPP for each pft though time in a time series plot or so.

Most vegetation models with fire modules kill plants at different times, which may not correspond to real circumstances. The grids that are not killed (disturbed) in a given year could have higher probability of being killed in the later years as the fuel load increases. Fire damage is also affected largely with the lack of soil moisture in later years. In this analysis we turned on the fire module for post-fire years, which resulted in such a pattern. As suggested, we will revise our figures to show aboveground biomass and GPP for each PFT through time.

L179-180: I am sorry, but I barely see any difference in delta NDVI between the burned and unburned areas. This is not very convincing, and it almost seems as if there is more of signal from the interannual variability in NDVI due to climate variability then a real fire signal. This entire analysis is a bit shaky; e.g. why do you take GPP for one single day instead of the mean of the month, which should be more representative of hence compare better with NDVI? And possible show the modelled delta GPP between a run with and without fire, instead of comparing between years, so that you only have the fire signal in your simulation results (now one cannot know what is the impact of climate and what is the impact of fire). It would also have taken the mean/median NDVI for multiple im-

ages to avoid impact of individual images (especially now that so much Landsat imagery is available).

We agree that the NDVI maps did not capture equivalent fire damage as suggested by the model and we will adjust this sentence accordingly. In addition, in a semi-arid system like this where moisture limitation is a major driving factor, climate signals could be strong enough to dilute the effects of fire. However, average annual values (Figure 7) do showed some reduction in NDVI from the fire, and the difference in NDVI between burnt and unburnt areas is slightly higher in the first year after fire. In this analysis we were not able to include mean monthly NDVI to compare against the modelled GPP output. We had to limit our comparison for late spring and early summer season when the productivity in the semi-arid ecosystem is sufficiently captured in the satellite images. We used Landsat images with a temporal resolution of 16 days, and there were several occasions when the satellite images were affected with clouds. We selected best images for a year, within the growing season and compared it against GPP output from same day.

In the revised analysis, we will compare our spatial model simulations with MODIS GPP and try to compute mean monthly figures (as we will have several observations in a month) instead of daily figures.

In addition, we will run spatial simulation for a control, ie. no fire condition for the current fire affected area. This will help us show the model behavior more clearly for damage and recovery caused by the fire.

L212-214: Would have been nice to see a comparison between the model and vegetation dynamics though time as given in the literature.

We will include this comparison in the discussion.

L 235: I don't understand what you want to say with this sentence.

We will rephrase. Our intention is to illustrate results from other studies, where fire-related damage behaved differently compared to satellite observations. As stated earlier, damage defined by these models may lag by a few years depending on biomass and soil moisture conditions.

L234: what do you mean with "annual variability"? I think the discussion needs some work to be more focused and understandable.

Thank you for your suggestion. We will revise the discussion for clarity.

Figure 1: include lon-lat and scale to have an idea how big your study area is.

Thank you for your suggestion. We will include the lat-long coordinates and scale in the figure.

Figure 2: include lon-lat and scale to have an idea how big your study area is. Indicate what that blob of high NDVI to the northeast is, as it is somewhat distracting.

Thank you we will update the figure and provide an explanation of the areas showing higher NDVIs (or MODIS GPPs) in the northeast (that are agricultural and suburban landscapes).

Figure 3: first sentence of the caption is confusing, shrub, grass and total GPP? Is Grass GPP put on top of shrub GPP?

Yes, we put grass GPP on top of shrub GPP. Both are stacked and represent a total GPP. We will make this clear in the figure caption.

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