Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2018-161-AC2, 2018

Geoscientific Model Development Discussions
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GMDD

Interactive comment

Interactive comment on "Simulating migration in dynamic vegetation models efficiently with LPJ-GM" *by* Veiko Lehsten et al.

Veiko Lehsten et al.

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Received and published: 20 September 2018

On behalf of the author team I want to thank the reviewer for the time invested in this extensive review.

Below is a point by point response to the comments raised by the reviewer. We will address the points in a revised version once invited by the editor to provide a new version of the paper.

Interactive comment on "Simulating migration in dynamic vegetation models efficiently with LPJ-GM" by Veiko Lehsten et al.

Anonymous Referee #1

Received and published: 19 September 2018

Overall Comments: The paper describes two approaches, for simulating seed dispersal in global-scale dynamic vegetation models. Vegetation migration in response to climate change (both past and future) is a major area of research, and the ability to simulate dispersal in DGVMs would be a major advance. There is certainly scientific merit in this manuscript, however there are numerous issues that need to be addressed. In general, since this is a paper about model development, more details about the model and justifications for their choices, need to be included.

Major Comments: Seed production (Section 2.3.1) For the entire section – "each grid cell", does this refer to the large grid cell or the smaller grid cells within?

Response: There are no smaller gridcells within gridcells in our model. Whenever we mention gridcell we mean the entire gridcell since we have not subdivided them. We simply use very small (compared to typical LPJ-GUESS uses) gridcells. In each run a gridcell all gridcells have the same size. However, we are only simulating a sparse field of gridcells, meaning that while all gridcells are taken into account for the seed dispersal, some of them (often many of them) are not simulated by LPJ-GUESS-GM, hence all seeds landing there will not germinate. We will stress this out in the paper.

L157 – "no specific age of maturity is taken into account". Maturation age has been shown to be one of the most important factors for determining tree migration rates (e.g., Nathan et al. 2011; Snell 2014). This is especially relevant for trees, as most tree species delayed maturation. Please include a justification for why this was not included.

Nathan R, Horvitz N, He YP, Kuparinen A, Schurr FM, Katul GG. 2011. Spread of North American wind-dispersed trees in future environments. Ecology Letters, 14: 211-219. Snell RS. 2014. Simulating long distance seed dispersal in a dynamic vegetation model. Global Ecology and Biogeography, 23: 89-98.

Response: In our implementation we are not aiming to make a model to fit the real world but rather to see whether our way to implementation leads to comparable results compared to TREEMIG. To be able to compare the results we tried to stick to the way it was implemented in TREEMIG, and there the start of seed production was based on the total height, hence this is what we implemented as well. Height is also a good indicator of maturity. However we agree with the reviewer that age has certainly its merits and might be a more suitable variable in certain conditions. We have in earlier versions used age as a trigger to start seed production. In the next version the user will be able to switch between tree age and tree height as a trigger for seed production. This information is missing in the paper. We will add this reasoning to the paper. The mentioned LAI is used to calculate the amounts of seed similar to Lischke et al 2006.

Comment: L159 – please clarify what is meant by “seed bank”, and perhaps use another term. In ecology, seed bank has a very specific meaning (i.e., the dormant seeds in the soil that can germinate in subsequent years).

Response: This is exactly what we mean. We will use this phrase to define seed bank in the text.

Comment: How long do seeds stay in this “seed bank”?

Response: The annual loss of seed germability hence the decay time for the seeds is taken from the values in the cited TREEMIG publication (for Fagus it is 0.8). It is a species-specific value though currently the values are similar for all since there is little literature comparing the different species.

Comment: Does each grid cell have their own seed bank?

Response: Yes. So seeds enter after dispersal has already occurred?

Response: Yes.

Comment Or is this a central seedbank that all grid cells have access to?

Response: No. Seed bank dynamics (decay, loss due to germination and new arrival due to seed dispersal). Is calculated independently for each gridcell. We have decided to keep the seed bank description short since we took exactly the same approach as in TREEMIG. However we will explain it more exhaustively in the revised version of the paper.

Comment: L160-160 – please provide a justification for why you chose the LAI approach for seed production, and not the carbon allocation approach already implemented in LPJ- GUESS.

Response: The currently implemented carbon allocation in LPJ-GUESS allocates a fixed amount of carbon to reproductive tissue which is then added to the litter pool. Here the basic unit is carbon rather than seed number, which is what we work with. The main reason why we did not go the way to change the amount of carbon allocated to reproductive tissue depending on seed weight and seed number is twofold. Firstly we did not want to change the carbon dynamics within LPJ-GUESS as this is the result of a lot of fine adjustments and any change in the NPP allocation requires a substantial testing afterwards to assure that no unwanted effects occur. Secondly it would have meant that we also need to take the lateral exchange of carbon between cells into account. Currently there are a number of checks that assure that the carbon cycle is closed. Apart from transferring more data between cells, we would have had to adjust these checks as well. So in essence we agree that it would be more reasonable to deduct the carbon for the seeds from the NPP and to transfer it to the adjacent cells (though I guess the amount of carbon actually transported outside a cell is very small compared to the one that stays inside). For the purpose of demonstrating the migration mechanism (focus of this paper) we consider it not necessary but in the next version of LPJ-GM in which we plan to simulate historical tree migration we will implement exactly this. We will comment on this in the paper.

Comment. In addition, please include some more information for how LAI is used to determine the number of seeds? Response: We will add the equation and the

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parameters to the paper.

Comment: What value was chosen for maximum fecundity?

Response: We used the same value as used in TREEMIG, we will add them to the paper.

Comment: Is this species specific?

Response: Yes.

Comment: Seed bank dynamics (Section 2.3.3) L191-193 – this explanation is not sufficient. What is the difference between yearly loss of germinability and the amount of germinated seeds?

Response: At the start of each year the amount of seeds that survived the last year is calculated. From this number the amount of germinating seeds is subtracted using a species specific fraction. Then new seeds arrive from the same gridcell and surrounding gridcells that are added to the seed bank the the cycle begins again. We will explain this in more detail in the paper.

Comment: Is there a single seed bank for each large grid cell, or each smaller grid cell inside? L194-198 – this is confusing.

Response: As there are no smaller grid cells within gridcells, there is one seed bank for each grid cell, of which all have the same size.

Germination (Section 2.3.4) Comment: L202 – 208 – why did you want to add more limitations to establishment? What is the biological justification for this? What does "we fixed this parameter to 0.01 after initial testing" mean? What properties did you evaluate? What does this parameter do? And how does your new limitation interact with the already implemented light limitation (i.e., does this filter happen before or after)?

Response: This parameter is a parameter which relates to the area of the gridcell (in which the seeds spread out). In LPJ-GUESS all simulations are done per square meter.

If the same number of seeds land in a larger area there will be less per square meter. As we do not change cell size here we fixed this parameter. Basically LPJ-GUESS simulates a certain amount of seedlings to establish each year depending on the amount of light reaching the forest floor. What we do here is to calculate a probability that the establishment event that LPJ-GUESS simulates happens depending on the amount of seeds available, hence we only decrease LP-GUESS's internal establishment. We will make this more clear in the paper.

Comments: Corridors (Section 2.5) This entire section is also very confusing - looking at the figures helped, but the text needs to be clarified. Are these corridors the large grid cells, or the smaller grid cells inside? Or both?

Response: As there are no small gridcells and large gridcells, but only one size of gridcells, the corridors are those gridcells in which the full LPJ-GM dynamics is calculated. The cells outside the corridors take part in the seed dispersal routine, but no vegetation dynamics is calculated in them. We will make this more clear in the text and mention repeatedly that there is only one size of gridcell however only on those on the corridors the vegetation dynamic is calculated by LPJ-GM.

Comment: L260 – 263 – How is the 1 km scale chosen, appropriate for a species with an average long distance dispersal of 200 m? Only a very, very small proportion of seeds would be able to travel 1 km or more.

Response: Yes it is a small proportion, but it is sufficient to establish the species in the next cell. But we agree, there is a discretization error involved, as in every spatial simulation. We will discuss that.

Comment: The next section (L285), mentions "parallel and diagonal corridors". What does this mean? This should be described in this section, with some additional details provided.

We thought it would be clear when looking at the figures. There are basically two types of gridcells (all with the same size). First there are the cells for which LPJ-GM calculates full vegetation dynamics and seed production (type 1). Secondly there are cells (type 2) for which LPJ-GM assumes a seed production similar to the nearest neighbor for which full vegetation dynamics is calculated. Hence there is a complete matrix of seed production for which one of the two described algorithms (FFTM and SMSM) is applied to calculate seed dispersal. Only in those cells for which LPJ-GM calculates the vegetation dynamics these seeds can cause trees to establish and to produce new seeds. These two types of cells are arranged in a way that the type 1 cells form a corridor surrounded by type 2 cells. Since the diagonal corridors are also parallel we agree that we wording is unfortunate. We will in the revision call them north-south, east-west, northeast-southwest and northwest-southeast corridors and explain this more extensively

Comment:

Results, Explicit seed dispersal (Section 3.1) It is not clear what results this section is talking about, nor how it relates to the rest of the manuscript. Referring to “pre-studies” is not helpful (i.e., these results are not part of the current manuscript? So why are they included?).

Response: This pre-study is not part of the manuscript but part of the supplementary material. And it is mentioned in the paragraph. The term pre-study is misleading and we will replace it and directly point to the supplement. We will mention the matlab supplement in the Methods where we will add a part about the performance of the different algorithms. We will also highlight the results in the Results section and discuss this in the Discussion section in the revised version.

Comment: There are also no values in here at all.

Response: Running times for FFTMS and SMSM are compared to a large detail in the table 1. We will point to in in the text here as well.

How much faster did the FFTM or SMSM perform compared to the explicit dispersal?

Response: In the early stadium of the work we did an explicit seed dispersal in LPJ-GM. It became quickly obvious that given current computation ability this would not allow us to simulate larger areas. We then developed the two methods (FFTM and SMSM). Re-implementation of the explicit dispersal algorithm only to show that it will be much slower would take a considerable time. Therefore we went a different way, by implementing FFTM and SMSM and explicit dispersal mechanism into a Matlab script. This allowed to concentrate on the running time needed for the dispersal mechanism, which is the since the dispersal algorithm is the focus of this paper. A direct comparison of running times required for the seed dispersal for the different algorithms for different area sizes is done in the script and the results are plotted in the pdf. The script also allows the user to simply cut and past the code into Matlab and play around with it.

Comment: Also, this is the first mention of a Matlab script (perhaps should be mentioned in the methods?).

We will do so. It was actually just meant as an add on to aid explaining the methods since if reading an implementation helps to be implement it in any other model. But since it is also used to evaluate running times we will cover it in the methods and results section in the revised version.

Comment: Since (I assume) the Matlab script doesn't include the additional processes from LPJ-GUESS, how comparable are these results to what you would get in LPJ-GUESS?

Response: In table 1 we are comparing the running times of the FFTM and the SMSM with the running time where seed production is calculated but no seed dispersal is performed, while in the Matlab script we are comparing only the seed dispersal calculations of the two new mechanisms and the explicit mechanism leaving out the vegetation dynamics. Hence though one cannot precisely calculate the difference, one can make a rough estimate. Table one lists the percentage of the time used for the dispersal for the FFTM method, Supplement 2 shows the increase in computation time for the dispersal algorithm between the FFTM and the explicit seed dispersal hence, by multiplying the time needed for the FFTM win table 1 with the factor from the figure in the Matlab script one can estimate the total difference. So as an example: The simulation of 100*100 cells with LPJ-GM uses in total 1800 cpu*h of which ca 200 cpu*h are used for the calculation of the dispersal (11%; table 1). According to the graph in supplement 2 the explicit simulation needs one order of magnitude longer than the FFTM hence a rough guess would be that instead of 200 cpu*h as used for the FFTM, an explicit seed dispersal would need 2000 cpu*h, which would increase the total required simulation time for 100*100 cells to 4000 cpu*h. One can see in the plot in the supplementary material, that with larger areas, the differences between calculation time of FFTM and supplementary material increases to two orders of magnitude. Hence for larger areas the calculation of the seed dispersal would dominate the required calculation time even more.

We will add this to the discussion.

Minor Comments L34 – not “at least”, which implies 1 km or greater. But should be “at maximum” implying that 1 km is the greatest size that can be used.

Response: We will change this

Comment L 37 – what is “it”? It stands for ‘simulating the local dynamics’ We will change this.

Comment L39 – what “both methods” are you referring to here? The comparison of the Fast Fourier transformation vs the iteratively shifting seed matrix, or the comparison of be- tween the simulations with all grid cells, versus the corridors?

Response: we mean FFTMS and SMSM and will name them in the sentence to make this clear. The corridors are not a method but a way of placing cells.

L39 – what does “reliable” mean?

Response: It means that for both methods (FFTMS and SMSM) comparable results are gained by calculating either corridors or the whole area. We will rephrase this.

L59 – awkward wording. Response: We will rephrase this.

L59-79 – both of these paragraphs are missing appropriate references. They have none, but include several statements which need to be referenced.

Response: The first paragraph expressed mainly the viewpoint of the authors, but we will try to find other papers which expressed similar viewpoints. The second paragraph clearly states facts and we will add the appropriate references in the revised version.

L95 – although this is explained in more detail in the discussion, it would be helpful to have this information in the introduction. (i.e., what did previous approaches do, and why were they limiting).

Response: We had in fact moved the review of other methods from the introduction to the discussion but will provide a small summary paragraph in the introduction section in the revised version.

L108 – 110 – a few more details about LPJ-GUESS? This one sentence is vague and particularly unhelpful for understanding what this model does.

Response: LPJ-GUESS has been described in 200+ publications (though most of them focus on a small side aspect or a new development that did not become part of the standard version). Finding the right amount of information given to the reader is tricky. We will extend the model description.

L127-128 – if all vegetation is killed, and now seed dispersal is active, you MUST have some vegetation or you won't have any seeds?? Where does the first generation come from?

Response: As described in 194-198, for some cells seed limitation does not apply until a certain point in time. These cells are the refugia of the species which have free establishment. In the example simulations these are the cells in the upper left corner. Hence after the clearing of the vegetation trees can establish freely here, produce seeds that can subsequently disperse to the surrounding cells.

L142-150 – please clarify this how this occurred. So instead of one grid cell with multiple patches, you simulated one grid cells with multiple grid cells? But these smaller grid cells, had spatial locations and could interact with each other (unlike patches)? This was my interpretation, but this needs to be clearer. A conceptual figure would help.

Response: We simulated only one patch per grid cell. However in typical LPJ-GUESS simulations, grid cells are as big as the climate data dictates, e.g. 0.5 up to 2.5 degree longitude/latitude. In our simulation, grid cells are small compared to the standard LPJ-GUESS size. Hence for the area simulated in one standard LPJ-GUESS simulation gridcell (with several patches), LPJ-GM would place many gridcells (with one patch). So there is not one gridcell with multiple gridcells, but just many small grid cells. We thank the reviewer for the suggestion to make a conceptual figure and will provide it in the revised version.

L188-189 – need more details about how these parameters were "roughly estimated" if this approach is to be applied in other models or for different species.

Response: The term 'roughly estimated' indicated that there is a high uncertainty connected to these values. There are parameters estimated for the main European tree species in Lischke et al. 2006.

L286-289 – this sentence is confusing.

Response: we will break up the sentence and make it more clear in the revised version.

Figure 5 is not clear – what is causing the white areas? Neither the results nor the methods addresses what the simulation set up was that could cause this pattern. The explanation "no seeds were able to reach them" is not true, as seeds obviously reached

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all the way around the white circles in the center (i.e., beech arrived in year 2500, but then never migrated in?).

Response: The main purpose of the simulation displayed in Figure 5 was to demonstrate a how the method performs when a certain seed dispersability is defined caused by a certain terrain. To demonstrate the effect we created areas in which the dispersability for the seeds were set to zero, hence they could not enter the grid cell. This is shown in the methods section in Figure 2 which shows the probability of entering a new grid cell. In the blue areas in figure 2 the cells have a zero probability of seeds entering from neighboring cells hence seeds can not enter the cell.

In the Results just above Figure 5 we currently write:

“Since the SMSM allows adjusting the probability depending on the seed transport permeability of the terrain we also simulated the migration within a non-homogenous dispersal area. The results of this simulation are displayed in Fig 5.”

In the description of the SMSM we write:

If this is done repeatedly <the seed shifting algorithm> it allows an easy implementation of spatial explicit differences in seed dispersal kernel distributions, by adjusting the proportions of seeds being transported into the next cell according to a similarly sized matrix containing the area roughness or permeability. By this approach, barriers and even wind speeds in latitudinal and longitudinal directions can be implemented by adjusting the dispersal probabilities accordingly.

<Figure 2 placed here>

In the results “Simulation experiments” section we describe the simulation run:

“For a specific simulation using the SMSM method we assumed differences in the dispersal ability (e.g. more or less permeable areas or physical barriers) while the climate on all grid cells is still static and favourable.

The reviewer correctly remarks that the information concerning this simulation is spread out, to aid the reader we will refer to this simulation as ‘terrain simulation’ as it is already called in the Matlab script. We will also add a paragraph in the discussion section explaining that the white features are caused by the low permeability of the cells leading to zero probability of seeds entering the cells and hence to no establishment of trees.

Comment:

Numerous small grammatical errors throughout (this is not a complete list, just a few examples). L25 GMDD Interactive comment L51-52, “to have a sufficient amount of seeds” L72 – unnecessary “of” L86 – unnecessary “the” L202 – “depending stochastically depending” L305 – “Using at a distance of” L347 – “..we are the first that manage to implement. .

Response: We will change these grammatical errors and check the text again for further grammatical issues.

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