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

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Interactive comment on "Simulating migration in dynamic vegetation models efficiently with LPJ-GM" by Veiko Lehsten et al. Anonymous Referee #3

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Lehsten et al. present a nice and timely study focusing on the implementation of migration into dynamic global vegetation models. They show a way to connect established assumptions of seed dispersal based on former studies with two approaches of enhanced seed dispersal based on Fast Fourier transformation and seed matrix shifting. Together with allowing seed dispersal through specified spatially equidistant corridors they show a nice way of how to reduce computation time while losing some accuracy

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Discussion paper

even though there is no real validation presented. The approach has the potential to be applied in the different DGVMs existing today and is an important contribution to their development. My comments mainly concern 1) the reproducibility of their method and 2) the realism of being able to conduct continental scale simulations.

Response: Thank you for the effort put in the review of our paper. We will respond and react to your comments as listed below. Line numbers will be added once the paper is finished.

Comment: Computation time: My biggest concern here is that the authors simulated only one species migrating. Therefore, they were able to simulate only one growing patch per 1 km2 grid cell. When increasing the species number it is definitively important to also increase the number of growing patches (and probably decrease their size to enable local competition or in other words to avoid an unrealistic growing patch overarching competition which is one of the major selling points of a gap model like in LPJ GUESS typically using 100-1000 m2 growing patches) in return increasing the computation time.

Response: Actually the whole concept of patches as independent replicates of the vegetation succession at one location is somewhat problematic with our simulation set up. For patches to be independent, there should be no interaction between them. However this is exactly what we want when simulating migration. It seems that the reviewer is under the assumption that we increased the patch size. We did not. The patch size is kept at the standard level of LPJ-GUESS 4.0 of 1000 m2. Similar to all other applications however, this patch represents a larger area. In most applications this patch represents an area as large as the climate grid cell (typically 1 (0.5) degree lon/lat). In our simulation the single patch per gridcell represents an area of 1km2 which is only important for the dispersal kernel. The patches in LPJ-GUESS are mainly introduced to take into account the stochastic heterogeneity of vegetation, that means to decouple the small scale successional stages, to be sure that for example an LAI value for a cell is not too low, simply because the patch is just in an early stage of succession,

Hence an averaging of many cells (which have a random disturbance event to restart the succession) will assure that this will not happen. In our case we have only one patch per grid cell, however, in a larger scale simulation one would of course average over 0.5 degree and in this case over 200 grid cells with a single patch and hence all successional stages should be present in this 0.5 degree with the correct proportion similar to an application in which a large number of patches would be applied.

Comment: The computation time for a continental scale simulation with many different species still has to be determined and could be topic of a follow up study.

Response: This point has been raised by the other reviewers as well. To run a truly continental simulation with many species is with the presented method at the current stage of optimisation not feasible. However, the main point of the paper was to present the two methods and not to spend a lot of time on optimisation methods. The main time in large scale simulations will be needed not by the simulation of the seed dispersal but by the simulation of the vegetation dynamics given that many cells will need to be calculated. We expect to be able to present continental simulations over the Holocene soon, but have currently no proof for this. Therefore we refrain from mentioning continental scale simulations and refer to 'larger areas'. Basically the found that the corridors can be placed rather far from each other over the largest areas of Europe, which would allow the continental scale simulations that we refer to. But again since we are not providing data on this we will not mention it in the paper.

Comment: Germination rate: It is unclear how sensitive the presented results are in connection to the germination rate used. Obviously the germination rate must influence the speed of migration. The rate of germination directly influences the competitiveness of each species and therefore its dispersal. Age of maturity: Even though I am totally ok with not taking into account an age of maturity to keep the findings of this study as simple as possible, it is again very obvious that this variable strongly influences the speed of migration. Therefore, this topic needs an extra space in the discussion or some results in the supplement showing e.g. the influence of assuming a minimum

age of maturity.

Response: We fully agree with this comment. Here we are using the germination rate used in TREEMIG and compared our results with the results in TREEMIG. In a 'real world' study this should be looked at in detail while here we only want to present the method. We do now mention that this in the Discussion where we changed the title of the section : 'Parameterisation of dispersal kernels ' to Parameterisation of dispersal kernels and other plant parameters'. And we discuss this in Line:. . .

Comment: Age of maturity: Even though I am totally ok with not taking into account an age of maturity to keep the findings of this study as simple as possible, it is again very obvious that this variable strongly influences the speed of migration. Therefore, this topic needs an extra space in the discussion or some results in the supplement showing e.g. the influence of assuming a minimum age of maturity.

Response: We agree, that the time a species needs to start reproduction, i.e. generation time, is one of the most important factors influencing migration speed. Instead of fixed age of maturity we use a height threshold for maturity, which makes generation time dependent on growth and thus on environment and competition. We emphasize it in lines . . .. and line . . ...

Comments: Line 132-134: How does the seedbank determine establishment probability and how is environmentally-suitable determined? I would like at least a brief explanation of this crucial aspect.

Response: While we mention the environmentally-suitability here, and the probability to establish, we explain the establishment probability in detail in Chapter 2.3.4 Germination. With respect to the environmental suitability, this is assessed in LPJ-GUESS (and we did not change this part) by using environmental envelopes of some climatological parameters, e.g. minimum temperatures to survive or establish. We now added an inset mentioning this and referring to the LPJ-GUESS publication at line . . ..

Comment: Line 136 – 150: So what I see in figure 3 and 4 is that for the 50km corridor approach you have 6 corridors per 0.5 âŮę grid cell (or do neighboring cells share corridors)? And these corridors need 200 simulation cells each of them 1km 2 in size? Assuming that a 0.5 âŮę grid cell is 50x50km I wonder where the positions of your corridors actually are. At the boarders of each grid cell and also diagonal through the middle? It would be helpful to this in Fig. 3 and 4. Response: We have inserted a figure of the sequence of local dynamics on the corridors, interpolation and dispersal on the grid, where we highlight the corridors (line . . .) However there seems to be another misconception. We are simulating an area of 100 by 100 km in all simulations. Each time each cell has a size of one by one km. So the cells are completely adjacent. In the simulations with the corridors we are selecting cells (all outside the corridor) for which we do not simulate the vegetation dynamics, but when simulating seed dispersal we interpolate the seed production from neighbouring cells. Hence in the step of simulating the seed dispersal we have again 100 by 100 cells (adjacent to each other) that produce seeds (though some just have the seed production value from the nearest neighbour). So to come back to your first question the 100 by 100 km would be roughly a 1 by 1 degree grid cell (in our simulations we need to run LPJ on equal area cells rather than lon lat as usual) and for the 50 km corridors you would have 2 East West, 2 North South, 3 NorthWest – SouthEast and 3 NorthEast –Southwest corridors (lines of cells at which the full vegetation dynamic is calculated).

Comment: b) You are able to use only 1 patch per cell, because you are only simulating 1 species migrating. It is important to explain in the discussion that you definitely need more (and probably smaller) patches if you consider more species. It actually scales with species number. Therefore, computation time would be much higher as well. This is contradicting potential continental simulations.

Response: Testruns have shown that we can have multiple species migrating with a single patch. We cannot see the logic why a single patch can only have a single species migrating. In fact the calculation in LPJ-GM simulates the seed dispersal for

both simulated species (which probably slows the simulations somewhat), though the birch has free establishment. We agree that more species will require more simulation time. However since this is using LPJ-GUESS and not LPJ it does not scale as strongly with species number since each species can have a multitude of species age cohorts and computation time scales with age cohorts. In a crowded cell there will be less cohorts per species but in general the statement that more species require more computation time holds true. We therefore removed all references to continental simulations in this paper. We hope to present a continental simulation soon in a different paper.

Comment: Line 155-157: Even though you cite Lischke et al. I would like to see a brief explanation of the “maximum fecundity” method.

Response: It is not a method but a single value for maximum fecundity. Basically there is a maximum number of seeds produced for which we have an estimate. This one we multiply with the current LAI divided by the maximum LAI for which we have a value listed. We now give an example to make this clearer at line . . ..

Comment: Line 157: Have you performed tests for age of maturity? I guess setting an age of maturity would lower the speed of migration. I am totally ok with not taking this into account, but it would be good to pick up this issue in the discussion e.g. under 4.4.3.

Response: As mentioned before we are using height of maturity (see chapters 2.3.1) and now discussing this in the chapter 4.4.3 Paramterisation of dispersal kernels and other plant parameters.

Comment: Line 163-164:Please provide explanation and reference for mast fruiting effects.

Response: We provided an explanation and added a reference. Lines . . .

Comment. Line 188 – 189: So do you use the values for Fagus sylvatica? Response:

Since the only species that effectively migrates in this paper is Fagus, we do use these values.

Comment: Line 191 – 193: Where can I find values of “loss of germinability”? If these are specific values from Lischke et al. I would suggest to list them in a table as well as similar parameter values. This would really help to reproduce the study.

Response: We agree with this and will make one extra table listing all needed parameters needed to reproduce the study in the appendix.

Comment: Line 194-198: I have my problems understanding this whole part. 1. “A year is defined for each species and grid cell before which seed bank constraints are ignored”. I do not understand this sentence. 2. I also do not understand the second sentence. I believe you talk about the initial conditions and refugia. It is probably a very crucial part for migration simulations so please provide a few more sentences of explanation.

Response: We rephrased the sentences to this (and hope it is now more clear): For each grid cell and each year we prescribe whether the species requires seeds to establish. By not requiring seeds in some cells for establishment or not requiring seeds for establishment for some species for all cells we define refugia or in the latter we define that the species’ seeds are known to be very far dispersed and hence no explicit simulation of establishment by seeds is required for this species. Technically this is implemented by reading in a list for each cell containing a year from which onwards a species’ establishment is not limited by the availability of seeds. Explained in lines . . .

Comment: Line 207: Explain “age cohort”. It has not appeared before and is important to understand the approach.

Response: The term age cohort comes from the general principles of LPJ-GUESS. Since here we only talk about the establishment of a species we decided to remove the term as it might only confuse the reader if we add a 3 sentence explanation. Line :

. . .

Comment: Line 199-208: Please provide equations and an according explanation instead of an example in

Response: We will add an equation to the new version of the paper.

Comment: b) Moreover, I am quite sure that the germination rate strongly influences results. It is probably important for the speed of migration and definitively for competition and therefore equilibrium biomass. What do you mean with “initial testing”? I don’t expect a comprehensive full explanation in the text, but I would like to understand why you have chosen certain parameter values.

Response: See above, we added a section in the chapter: 4.4.3 Parameterisation of dispersal kernels ,and other plant parameters

Comment: Line 302 – 303: As suggested above. Please provide the numbers of your parametrization.

Response: All parameters will be listed in an extra table in the supplementary material

Comment: Line 442 -443: Is it possible to give a comparison here? What is the computation time for the same setup with standard LPJ-GUESS? I see your comparisons in table 1, but they all refer to simulations which use a master. Response: We will add a simulation with LPJ-GUESS without any extra code.

Comment: Line 488 – 490: Have you estimated the CPU hours for this setup? Would be an interesting information.

Response: Yes we did. We tested using the FFTM (hence without terrain) using 4000 by 4000 grid cells, running for a few years only. Looking at the numbers in table 1 shows that running a full scale simulation with 21000 years over the 3463 $\frac{1}{2}$ degree cells that we typically use for European runs would take a long time: 1800 (CPUh per 100000 cells and 3000 years) /100000(cells in the MS)*3463(half degree cells in

Europe) *50*50(rough estimation of how many 1km cells are in a half degee cell)) *21000 years in LGM simulation / 3000 years in a test simulation gives us roughly 10 mill CPUh. Given that my current account allows me 45000 CPUh a month that is currently not feasible and that is why we suggest the transect method. (Actually there might be even more time needed given that there are more than 2 species in the final runs). Again we see quite some opportunities for optimisation unused and will hopefully soon provide a continental simulation.

Technical comments: Line 22-24: Indicate that this sentence is about plants in the real world

Response: We now start the sentence with : Pollen studies have shown that ..... indicating that we are not talking about simulated species anymore.

Comment: Line 62-64: For me this is one of the major selling points and I would put it in the abstract as well. You decide.

Response: Thanks for the suggestion. We would love to do this and in fact we just started a project where we look at the spread of alien species, however what we present here is only considering tree migration. For trees the spread by adjusting to climate change is very slow given the long generation time. We will hopefully soon have a model in which we simulate tree pests spread, there this applies, but in this publication we only consider trees hence the response to current climate change is rather of second order.

Comment: Line 202: 2 times the word “depending”

Response: Thanks for spotting this. We removed it.

Comment: Line 203 -205: Confusing sentence. “The probability that a species establishes is proportional to the seed number in the seed bank multiplied by . . .”. Wrong formulation.

Response: We now added an equation instead of this sentence.

Comment: Line 206: The word “year” is missing.

Response: No the word ‘per’ was obsolete. Thanks for spotting this. We removed it.

Comment: Line 242: I would not expect that every reader knows what a Moore neighborhood is?

Response: We now added” i.e. the surrounding eight cells”.

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