Interactive comment on "Canal blocking optimization in restoration of drained peatlands" *by* Iñaki Urzainki et al.

Alex Cobb (Referee)

alex.cobb@smart.mit.edu

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General comments:

This manuscript consists of a simple, quasi-hydrologic model for water level in ditches (involving a graph problem) plus a simple hydrologic model for flow in non-ditches. These models are used like a management tool to evaluate the impact of ditches on ground water levels and greenhouse gas emissions in the peatland. The scientific question is worthy. It is not obvious that it falls within the scope of BG; however, it does involve interaction between organisms and the geosphere in the sense that organic decomposition is responsible for the emissions that are inferred from the water table estimates. It seems to me that if Hooijer et al (2010; doi:10.5194/bg-7-1505-2010)

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had a place in this journal, then so too does this manuscript. I have not seen such an exploration of peatland ditch blocking as an optimization problem in the literature. So the observations here, as well as some of the strategic decisions that the authors reached while designing their procedure, are novel, interesting and potentially useful.

In my view, the most valuable contributions of the paper are:

1. Showing that this problem is worth solving, in the sense that computer optimization of canal block locations worked much better than manual placement based on expert rules (though these rules are not sufficiently explained; see specific comments).

2. Showing that heuristic global optimization routines, in particular, can be valuable tools in attacking practical problems of this nature.

3. Suggesting that an initial optimization step of maximizing ditch water level could provide good starting steps for a more computationally expensive analysis of water levels within peat.

4. On a more technical note, the imposition of Dirichlet conditions in the domain interior using an implicit source term is a potentially useful approach for similar problems (though also not sufficiently explained; see specific comments).

The literature review is somewhat weak, in particular with reference to the tropical peat literature, and needs to make a clearer distinction between findings from higher-latitude and tropical peatlands. However, these additional references will not greatly change the narrative.

The results and the methods described appear valid and give no cause to suspect problems, and the simulation code has been made available (commendably). However, there is not enough detail in the manuscript to understand, even broadly, some aspects of what was done. I believe these clarifications can be made without adding supplementary material. See specific comments. The model for drydown in peat outside the canals is probably not very accurate (see specific comments), so accuracy for

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this specific case is somewhat questionable, but this does not affect the main contributions noted above.

The manuscript is well structured overall. The abstract should broadly outline the methods that were used (simulated annealing, genetic algorithms, Boussinesq, three days' drydown after initial "reset"). The Methods and Discussion would benefit from a minor rearrangement of sections (see specific comments). The Discussion is reasonable, concise and avoids overreach.

There are three limitations that do not compromise the value of the manuscript but should be touched on in the Discussion and / or Introduction (for more on all of these, see specific comments):

1. Examining the area in Google Earth, it appears there are many field drains in rectangular arrays of about 60 m x 250 m that are disregarded in the simulations because of the grid resolution. Though this does not compromise the value of the paper, it does reduce the accuracy of the results and should be made clear to the reader in the Methods section and emphasized a bit more in the Discussion.

2. In practice, the expected head difference across a block is an important design criterion that was not considered in the optimization.

3. The effect of canal blocking on methane emissions should be part of an overall evaluation of impacts but relevant experimental data from tropical settings are lacking.

Specific comments:

- P1 L2, Abstract: "Ecosystem restoration can be achieved by raising the water table": "Achieved" is a rather strong word; rewetting seems to be a necessary but not sufficient condition for tropical peatland ecosystem restoration.

- Introduction: unclear to a reader which results have been described in the tropics. Please distinguish references from higher-latitude peatland studies; in particular, blanket peats are rather different systems from the lowland tropical peats examined here.

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One approach could be to start by talking about peatlands in general, and then shift to discussing what is known from the tropics specifically.

- P1 L15: Additional references regarding peatland carbon pool: Nichols and Peteet 2019, Le Quéré et al 2018, or for a review, Page and Baird 2016.

- P2 L21: For peat subsidence in the tropics, see also: Couwenberg et al 2010, Hooijer et al 2010, Carlson et al 2015.

- P2 L22: Fire risk in peatlands: see also: Usup et al 2004, Page and Hooijer 2016.

- P2 L25: World Resources Institute: can you find a peer-reviewed (primary literature) source that makes this or a similar point?

- P2 L25-26: For CO_2 emissions from drained peatlands in Indonesia, consider also Miettinen et al 2017.

- P2 L27: "key variable controlling CO_2 emissions": add "from decomposition in tropical peatlands"

- P2 L27-28: By this point, it would be less confusing to focus on tropical references for CO_2 emissions vs water table depth; instead of Wilson et al 2011, consider Carlson et al 2015.

- P2 L33: Similarly, instead of Päivänen and Hånell 2012, consider Jauhiainen et al 2008, Ritzema et al 2014, Dohong et al 2018.

- P2 L35: Use tropical references again, then something like, "Studies of canal and ditch blocking in temperate peatlands have found that..."

- P2 L39: "This is especially important in tropical peatlands, where the canals are typically large:" Can a reference be provided? Armstrong et al (2009) describes the typical size of ditches in blanket bogs of the UK, and could be used as a point of contrast.

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- P2 L50: Near: "Global optimization methods are commonly used...": Provide a very brief introduction to the terminology you use from optimization theory; I would guess that a majority of Biogeochemistry readers will not be able to infer what is "global" about global optimization, what is meant by "design space", nor why it is relevant that the design space is discontinuous and non-convex. It can be short.

- In the same place, you should very briefly introduce simulated annealing and genetic algorithms.

- Section 2, Materials and Methods: I suggest starting with the site description; reasons discussed further below.

- P3 L62: Can you come up with a different phrase or modifier for "the hydrological model", as the canal water level subroutine is also in some sense hydrological? Perhaps "peat hydrological model".

- P3 L66: "target variable": I believe this is the only place this phrase is used in the manuscript; consider changing to "objective function" to reduce the number of new terms for unfamiliar readers.

- P3 L67: "We also tested an alternative, simpler optimization approach (SO)": Simpler than what? Could be easier to follow if the SA and GA optimization approaches are introduced first.

- P3 L73: "This subroutine calculates the CWL after buiding a set of blocks, v', based on their positions, k." As written, it is not clear to what v refers (a set of blocks? blocks?), nor why it carries a prime ('). I suggest something like: "This subroutine calculates the CWL v' after building a set of blocks at positions k based on the original CWL v."

- P3 L74: "the CWL is assumed to be at a fixed distance, wd, below the peat surface, s...": Here, I ask myself: is wd a product? For this reason, I would discourage using compound symbols like this, but if they are used, please clarify in some way that this is a single symbol (perhaps by referring here to the nice table of symbols).

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- P3 L75, Eqn 1: Does i index over pixels? if so, how is the peat surface elevation s defined in a canal pixel? It looks like the DTM pixels are much larger than the canals are wide, so I guess that s was derived directly from the DTM elevation? This would be easier to follow if the site (and DTM) were described first.

- P3 L76: "the value of wd was determined by direct observation...": Where? If at the site, it would simplify things to put the site description first. Otherwise, refer to that section.

- P3 L77: What is the "head level" of a block?

- P3 L78: Change "further up the canal network" to "upstream".

- P3 L77-81: Explain how "upstream" is determined prior to stating that a canal block causes the water in all upstream canal pixels to rise to the same level.

- P3-4 L77-85 and Appendix A: I think "direct causal contact" or "direct physical contact" does not convey what is meant here; it would be good to find a better phrase. How about talking about "contiguous upstream pixels", and explaining that "contiguous" means not separated by a canal block?

- P4 Figure 2: In this figure it becomes clear that v is positive up, and it appears that wd is positive down (if water table is further below surface s), but it is still not clear until Eqn 3 that WTD is positive up (even from Table 1). It would be good to mention this earlier, perhaps in Table 1, because "water table depth" causes different people to picture different things (does "a greater depth" mean the water table is higher or lower?). Throughout, I would suggest instead using "water level", after Bechtold et al (2014).

- P5 L90: Regarding the applicability of the Dupuit-Forchheimer assumptions: Insert "much", changing "for domains wider than they are thick" to "for domains much wider than they are thick".

- P5 Eqn 2: From Eqn 4, I believe that transmissivity T is a function of both the water

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table h and the elevation of the impermeable bottom ib, so if the functional dependence of T is written, it should be T(h, ib) rather than T(h).

- P6 L96-97: How was time stepping handled? Explicit, implicit? How was convergence determined? From later in the page, it looks like time steps were fully explicit in the functions T and Sy (the value from the beginning of the time step was used)?

- P6 L99-100: "The value of h at the canal pixels was forced to be equal to v' by adding an implicit source term large enough to completely dominate the matrix diagonal": What was done exactly?

- P6 L110-114: Move the sentence "The van Genuchten function was used..." to before the sentence "In absence of measured..." (assuming that data from Päivänen 1973 were used to parameterize the van Genuchten function?)

- P6 L110-114: Plot the resulting specific yield and transmissivity functions. Transmissivity could be plotted for the lowest substrate elevation, for example (or curves with different substrate elevations could be plotted together).

- P6 L115: Were the values of T and Sy from the beginning of the time step used during time stepping? In any case, depending on the transmissivity function, I would guess the time discretization error with a daily time step could be substantial. But, the error could be acceptable as a tradeoff against runtime (at least when finding good candidate block positions). Convergence could be tested via multiple runs with decreasing time steps, but in my view is not strictly necessary for this paper.

- P6 L118-120: The broad outline of the simulation scenario (3 days of drydown from an initial "reset") are an important part of (SA and GA) objective function evaluation and should appear in the Abstract and the end of the Introduction.

- P7 L128: Does the spatial average of water table depth include canal pixels?

- P7 L128-133: I suggest dropping the subscript for the number of days averaged; it does not seem important for explaining the results and removing it would allow remov-

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ing an equation (7).

- P7 Eqn 8: I am confused about sign issues in this equation (and / or Eqn 9). If I understand correctly, zeta is positive up, so this equation seems to suggest that emissions are larger if the mean water table is higher, which is surely not what is intended.

- Eqn 9: Are these parameter values, as well as the affine assumption (Eqn 8), from Jauhiainen et al 2012? If so, add a citation immediately after Eqn 9.

- P8 L149-150: "Let k = (k1, ..., kn) be the vector of block positions": How about: "Let k = (k1, ..., kn) be the boolean vector indicating presence or absence of a block in each canal pixel..."

- P8 L158-159: "design space", "search space": pick one, and use it also in the Introduction (P2 near L50).

- P8 L164: "Genetic algorithm... and simulated annealing... can find the global minimum with high probability": true for some problems, but it is not hard to cook one up for which they would not have odds that are good at all; for example, imagine an objective function that is 0 at a single point in the plane and 1 everywhere else. How about, "... can often find the global minimum in many problems."

- P9 Table 2: The empty column under "rule-based" is confusing. How about putting something here, like "Manual", or otherwise removing the column and simply describing it in the table caption.

- P9 L195-196: Regarding the rule-based configuration: What were the rules?

- P10 Eqns 15 and 16: It is not clear to me why an absolute value was used here. Why not just order the operands so that improvement in the mean WTD (higher water level) results in a positive value? Surely, if an intervention were to somehow lower the water table, this should result in a negative value (even if none of these interventions did so).

- P10, section 2.2, Study area: How was the DEM derived?

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- P12 Figure 5: Nice figure. I guess the multiple water level lines are for the 3 consecutive days of drydown?

- P13 L248-249: "An informative way to gauge this difference...": where can I see this in the data?

- P14 Figure 7 caption: What is meant by "The random range was linearly interpolated"?

- P15 Figure 9: Improve caption; not obvious what is being shown without reference to the text.

- P16 L287: "this work introduces the first systematic tool..." It's hard to be sure; there could easily be something like this in use by large private landowners. How about "the first freely available tool" or "the first published study"?

- P17 L301: "the three-day average of the WTD would 2.13% units lower": I don't follow; where is this shown?

- P17 L306-: "Some remarks about the assumptions...": This would be a good place to mention any other limitations of the DEM. How was it derived? Do you believe it to be highly accurate?

- P17 Section 4.2: This section starts by talking about the rule-based method, then discusses the optimization results, and then comes back to compare the optimization results to the rule-based method. This section could be made easier to follow, and some redundancy might be eliminated, by starting with the optimization results and then contrasting the results from manual (and random) block placement.

- P17 L322: "The positions for the blocks in the rule-based approach were based on the contour map..." Derived how? Besides explaining this in the Methods, it would be good to briefly mention the criteria for manual block placement here.

- P19 L370-379: The discussion of why the idea of steady-state Boussinesq solution

was rejected could be condensed.

- P19 Section 4.3: In this section, it would be good to at least briefly mention the possible effects of canal blocks on methane emissions from ditches. From higher-latitude peatlands there are a number of studies, in Finland and elsewhere, e.g., Minkkinen and Laine (2006). In the tropics much less work has been done; without doing a search, I am aware of these two: Jauhiainen and Silvennoinen (2012), Manning et al (2019).

- P19 L384-385: 80 blocks results in about 14 km between blocks: you could state more explicitly that your method remains applicable for placement of a larger number of blocks (at the expense of more computing time). This could be a good place to mention the typical design criterion, not considered in this study, of avoiding large head differences across blocks to prevent dam failure (per general comments).

- P19 L392-394: Good point but phrasing could be improved.

- P20 Algorithm 1: v'A <- vA + hl: Appears not to match Figure 2, or Table 1; looks like it should be v'A <- sA - hl.

Technical corrections:

- P1 L4: Change "water level raise" to "water level rise".

- P3 L77: Change "its water level raises up" to "its water level rises up".

- P4 Figure 1: The references to text sections look wrong (assuming that is what they are?): I guess 2.2 in "Canal water level subroutine (2.2)" should be changed to 2.1.1, etc.

- P8 L170: Change "the only parameter" to "the sole parameter".

- P8 L172: Add quotes around "individual", because it is being used in the GA sense of an "organism". Change 'individual k' to '"individual" vectors k'.

- P8 L174: "our implementation": the analysis used an existing implementation of the

algorithm, no? Perhaps, "... were the only parameters in the genetic algorithm implementation we used."

- P9 L177: Change "wide spread classical single processor algorithm" to "single processor algorithm".

- P9 L188: Change "over 10 processors" to "on 10 processors".

- P10 L222: Change "sappric" to "sapric".

- P11 Figure 4: Colors for "2 m" and "8 m" bins are hard to distinguish; why not use another continuous scale?

- P13 L262: Remove "eloquently".

- P14 Figure 7: What are the plectrum-like markers?

- P14 Figure 7: How do I find the "natural" and "drained" areas discussed later in the text?

- P14 Figure 7: In the plots, make the markers bigger. They are hard to distinguish, and it is hard to make out their colours and shapes.

- P15 Figure 8: Move labels away from markers to make them easier to read.

- P15 Figure 8: Make it more obvious to the reader what is better and what is worse on the vertical axis.

- P15 Figure 8: CWL change (m) ranges to 1000; unit error? Or is this a sum?

- P16 Figure 10: Text for legend is very small; move outside axes? Or, consider labeling the lines directly; it takes some work, with reference to the caption, to figure out which line is which.

- P16 292: Change "lowers" to "decreases".

- P18 L340: Change "any" to "every".

- P20 L418: Change lh to hl.

References:

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