Earth Surf. Dynam. Discuss., 1, C141–C147, 2013
www.earth-surf-dynam-discuss.net/1/C141/2013/

Earth Surface Dynamics
Discussions
Open Access

Interactive comment on "The role of hydrological transience in peatland pattern formation" *by* P. J. Morris et al.

P. J. Morris et al.

p.j.morris@reading.ac.uk

Received and published: 2 September 2013

We are grateful to Prof. Roulet for a detailed and thought-provoking review, and we are encouraged by the positive overview in his first paragraph (page C101).

In response to Prof. Roulet's specific comments:

P35 L3 and Fig. 1: We agree that our simulations with Models 3 and 4 are more representative of raised bogs than of fens. Nonetheless, Fig. 1 provides a convenient illustration of the kind of contour-parallel striped patterning that is common to various types of peatlands. Moreover, and as Prof. Roulet also notes (page C104; see also below), Models 1 and 2 are arguably more representative of fens. As such we believe it appropriate for the photograph in Fig. 1 to remain.

P40 L4: We agree that differences in water-table heights between hummocks and hollows might negate (at least in part) any differences in transmissivity caused by contrasting hydraulic conductivity. We believed that assigning a single, canonical value of transmissivity to hummocks and another to hollows (thereby ignoring water-table position) was an oversimplification that may have biased Model 1's behaviour, and that of the original SGCJ models. It was for this reason that we decided to use DigiBog's more sophisticated numerical scheme to calculate transmissivity as a continuous value for each grid square (the product of water-table height and depth-averaged hydraulic conductivity). This improvement is the sole difference between Models 1 and 2, and allowed us to circumnavigate the problem described by Prof. Roulet. In the end, though, there was very little difference between the behaviours of Models 1 and 2, which may be taken to suggest that this issue had not led to any artefacts in our Model 1 or in previous studies.

P40 L12: Although DigiBog does allow for continuous depth variation in peat properties such as hydraulic conductivity (K), we opted to experiment with simple profiles (constant K in Models 1 and 2; two-layered K in Models 3 and 4). This was because we wished to start by replicating the assumptions of the previous SGCJ authors where possible, and then to add to their models incrementally (see also our response to the comment on P49 L1-3, below). We agree that it will be interesting to go beyond these simple profiles in future models. In particular, future patterning models that simulate changes in K and other peat properties as continuous functions of decomposition (which we suggest in the Discussion as an obvious next step for research) will allow an exploration of the effects of fine-scale, continuous depth variation in K upon patterning.

P41 L6: To clarify: firstly, Models 1 and 2 had an impermeable base with a constant slope of 1:50 and a constant peat thickness of 0.2 m, whereas Models 3 and 4 had an elliptical cross section and a flat impermeable base, so that the thickness of the permeable peat decreased elliptically from the centre of the bog to its margin; secondly, we did consider the possibility of an intermediate model between Models 2 and 3 (see

ESurfD
1, C141–C147, 2013

also our response to Anonymous Referee #1; top of page C49), but decided against it because we felt the addition to the manuscript would do little to aid the pursuit of our objectives and would likely dilute our main message and confuse readers by adding yet another model; and thirdly, the cross-sectional shape of the bog used in Models 3 and 4 was not generated by DigiBog, but by Ingram's (1982) groundwater mound equation, as we state in the Models and Methods section (P41, L11-12). We concede that we could have made this third point more clearly in the manuscript, and we intend to remedy this in our revisions, perhaps by reworking some of the text from the beginning of our next point, below.

P41 L16-18: We would remind readers that the version of DigiBog used in our article does not simulate explicitly the processes of peat formation or decomposition, and therefore does not incorporate a peat mass balance. Rather, the model represents plant community succession as a shifting mosaic of scale-level 1 (SL1; 1 $\times$ 1 m) tiles superimposed onto a static peat landform. Nonetheless, Prof. Roulet raises an interesting point, which we already address in part in the manuscript. The time taken for a developmental step could be interpreted in one of two ways. If one were to take the value of delta-t_e (the hydrological submodel equilibration time) literally then a developmental step has a length of between 1 hour and 2 years. Clearly, however, and as we state in the Discussion (P47 L21-27) and in the Conclusions (P52 L14-17), developmental steps of hours to days are largely meaningless in terms of plant community succession. However, an alternative and more abstract interpretation of the model's dynamics allows one to conceptualise the length of a developmental step simply as a measure of hydrological steadiness under which succession takes place. With this in mind, we can think of succession as taking place over a period of years, during which the degree of hydrological steadiness is set or defined by delta-t_e. Therefore, delta-t_e is no longer a literal time period during which plant community succession occurs but a means of representing hydrological steadiness.

P42 L8-9: We disagree that we have not experimented with the effects of a seasonal delivery of rainfall to the model. Model 4 is driven by a time-series of net rainfall data, derived from real rainfall data from the calendar year 2011 at a raised bog in northern England. As can be seen in Fig. 4 of the main article, for the time series we used, late winter to early spring (approximately day 60 to day 120) was noticeably drier than the rest of the year. There is also a large, spiky input of water to the model from the large storm on day 222. Admittedly, the seasonality in Model 4's rainfall delivery is less extreme than that described by Prof. Roulet for peatlands with a strong snowmelt component, but patterned peatlands nevertheless develop in temperate climates where seasonal changes are less pronounced. It may well be that the magnitude of intra- (and also inter-) annual variability has an effect on the strength of peatland patterning, and this question might be taken up in future studies.

P42 L21-24: The purpose of using a time-series of rainfall data in Model 4 was to distinguish the effect of transient water tables from the effect of short equilibration times. This we achieved by cycling repeatedly through a single year of rainfall data. This allowed us to address our objective without adding the confounding effects of inter-annual variability.

P 43 L7-9: Our research led to two main findings: firstly, that patterning breaks down under what might be thought of as 'genuine' steady-state hydrology; and secondly, that patterning is highly sensitive to the absolute values of the parameters used to represent peat permeability (be it transmissivity or hydraulic conductivity). In both cases, the most important distinction between simulations is that striped patterning is either present or absent, and this distinction is very clear to the human eye. Quantifying the strength and particular nature of patterns between simulations is an interesting, but in our case secondary, issue. So our answer to Prof. Roulet's question is yes, we believe the human eye is sufficient for our purposes. Nonetheless, we agree that statistical image analysis techniques would present a potentially powerful and quantitative way to go about comparing pattern shapes, densities, strengths and so on between simulation models and real peatlands. Of course, such a comparison would necessarily be limited by the availability of suitable validation data.

P 43 L23-25: We agree that the downslope migration of pools might mean that the youngest pools are at the centre of a raised bog. In what is, to our knowledge, one of the few studies into the matter, Foster and Wright (1990) found that pool age decreased towards the margins of a raised bog in Sweden – seemingly in opposition to the trend suggested by the model, and also in conflict with the findings of Kettridge et al. (2012). However, Foster and Wright (1990) found that the outward growth of pools was closely linked to the rate of lateral expansion of the peatland, meaning that the pools formed as the bog expanded and then apparently did not move. The issue is further complicated by the fact that in a laterally expanding bog the surface slope is continually changing. As such, simulating lateral expansion of the peatland as a whole may be an important requirement for linked models of peatland patterning and peat accumulation. We will include a brief mention of Foster and Wright's work in our revised discussion.

P45 L16-22: We agree that the thin peat layer and the throughflow hydrological setting of Models 1 and 2 mean that they are arguably more representative of fens than of raised bogs; this is perhaps the strongest justification for leaving the existing photograph in Fig. 1 (see above, and Prof. Roulet's first specific comment on page C102).

P 47 L3-7: We intended no ad hominem criticism of the SGCJ authors. Of course, we meant to say "the SGCJ models" and not "the previous SGCJ authors". We apologise for this error and will alter the wording accordingly in the revised manuscript.

P47 L17-20. A good point, with which we agree.

P47 L24-27 We are grateful for these thought-provoking comments. We agree that the water table may behave more dynamically (have greater rates of fall after rainfall) when it is shallow (or perhaps when it is rising) due to higher saturated hydraulic conductivity near the surface. However, one might also expect this behaviour to be partly tempered by higher porosity in near-surface layers. It seems to us that the depth profile of the ratio of hydraulic conductivity to effective porosity is the most relevant quantity in determining water-table transience, along with the temporal regime of rainfall/snowmelt delivery. The question of pattern configuration upon water-table geometry and transience is also interesting; we have previously looked into this matter in part in an earlier publication (Baird et al., 2009).

P48 L1-4: Yes, we would argue that Model 4 is the most realistic and possesses what one might think of as a 'true' ombrotrophic hydrology.

P48 L12-17: As mentioned above, the version of DigiBog we used does not simulate peat formation or decomposition, and so does not incorporate a peat mass balance. It would, however, be possible to address this question with a linked model that simulated both patterning and peat accumulation (and their interactions), which adds further weight to our suggested direction for future research.

P49 L1-3: It is important to point out here that we are examining a theory (the ponding mechanism) and trying to ascertain whether it provides a satisfactory explanation of a real-world phenomenon (patterning). A good approach with any modelling enquiry is to explore simple models first and see whether they offer sufficient explanation of the phenomenon under study. If they don't, then consider a more complicated model. We have investigated the SGCJ models because they are widely cited and because they are thought to offer a viable explanation of pattern formation. Through our numerical experimentation we have been able to identify other factors that may be important in pattern formation: notably transience, but also feedbacks with peat accumulation. Therefore, to adapt George Box's famous quote: we know our model is wrong, but we believe our exploration of it has been useful.

P50 L13-17: As Prof. Roulet points out, and as we also suggest in our Discussion, it is possible to make a case for multiple feedbacks to be incorporated into future models, and a dynamic link between decomposition and peat hydraulic properties is certainly one of these. Experimenting with the effects of such a mechanism would be a priority for a linked model of pattern formation and peat accumulation.

Interactive comment on Earth Surf. Dynam. Discuss., 1, 31, 2013.

ESurfD

1, C141–C147, 2013