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Discussions

Interactive comment on "Flood risk reduction and flow buffering as ecosystem services: a flow persistence indicator for watershed health" *by* M. van Noordwijk et al.

Anonymous Referee #2

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As I understand the article, the authors are attempting to develop a single measure of watershed health called 'flow persistence' (Fp). This Fp parameter measures the volatility of daily river flow in response to land cover change within large catchments. One of the key objectives of the study is to determine the value of specific land cover types in terms of flood mitigation. The study itself is broken down into two phases: (1) the derivation of a river flow algorithm, and (2) the application of the algorithm within four watersheds with different rainfall and land cover characteristics. The key points that need to be addressed include: 1. A better justification that flow predictability does in fact correspond with watershed health; 2. A better explanation of the flow persistence derivation; and 3. A much more thorough explanation of the Fp algorithm application

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within the four catchments. The study addresses a significant point of contention in the literature: the influence of land cover (particularly forests) and flooding at the watershed scale. If the Fp model is properly justified and performs adequately, then it would undoubtedly increase our understanding of the linkages between land cover and flood risk. The benefits of such an approach are clear as it would make for a much more parsimonious model of river flow that would greatly enhance the monitoring and prioritization of specific landscape management decisions. That said, the paper requires substantial work to adequately address the points above and may need to be split into two separate papers. I will address the three points I mentioned above in greater detail below. There are quite a few of typographical and grammatical errors in the paper, but I will leave these alone for now as the paper requires substantial work.

Point 1 In the paper the authors use persistence, predictability, and watershed health interchangeably. One of the key assumptions of the paper and previous watershed rehabilitation efforts is that increasing the presence of natural land covers (particularly forests and wetlands) will restore the natural flood regime with lower peak flows and less damaging flood events. The authors do a good job of documenting previous studies that have illustrated the complexity of the linkage between reforestation and river flows. Moreover, the ability of wetlands and riparian forests to absorb rainfall, slow streamflow, and attenuate peak flows is supported by many studies and is fairly well understood. However, these types of stream corridor ecosystems also require a particular type of disturbance regime that creates opportunities for species specific recruitment processes and establishes landscape and topographic heterogeneity that are critical components of watershed health. These disturbance regimes are often characterized by variable flow patterns with various flood magnitudes required for specific types of ecosystem level processes. Most efforts to create a stable and predictable flood regime have been anthropogenic in origin through engineered based interventions like dams, and retention and detention ponds, which are also some of the primary drivers behind the degradation of watershed health. A perfectly stable flow regime could, theoretically, be established by a highly integrated system of engineered solutions (albeit until

they are either overwhelmed by a storm or undermined by system failure) within a very ecologically degraded watershed. Likewise, there could, theoretically, be examples of ecologically well connected and healthy watersheds with fairly volatile and unpredictable daily flow regimes. To overcome this, the authors need to discuss what exactly watershed health means and whether or not a predictable flow regime is the product of an ecosystem service. I could see an argument in which the shape of a storm specific hydrograph within a healthy watershed should be fairly predictable, however, to study this would preclude the advantages proposed by this paper (i.e. the application of the Fp algorithm in data sparse regions). I also agree that more human development and less natural systems generally leads to more flashy river flows as a result of decreased buffering capacity, however this study examines flow rates at daily intervals which washes out the ability to assess this linkage. Or maybe I'm missing something. The authors do point out later in the paper that Fp of zero (i.e. low predictability) would be the result of erratic rainfall (page 7 first paragraph). This is somewhat confusing because most of the introduction and discussion is focused on using Fp as a way to summarize "complex land use mosaics". Two paragraphs later the authors state "a decrease of Fp indicates watershed degradation." So how much of the decrease in Fp is explained by watershed degradation as opposed to just more erratic rainfall? I know the authors say that the GenRiver model is spatially explicit, but this is a little vague. Does this mean that spatial autocorrelation in precipitation is controlled for or that the model is spatially distributed? I understand that to have an Fp equal to 0 would require erratic rainfall, but the authors need to be consistent when describing what proxy measurements that Fp is suitable for. Figure 1 gets at the interconnection between many different elements that influence the hydrological cycle, and the authors break up the components into ecosystem structure, function, and human land use/perceived ecosystem service. However, I find the figure difficult to navigate and poorly described in the study. The different color arrows with different shades and outlines is one of main culprits of the confusion. The graphic needs to be simplified, it should probably start with rainfall, and terms like "plot-level" should either be defined or removed.

Point 2 An Fp value ranging from 0-1 essentially represents the buffering capacity of the watershed, but there are also characteristics that influence how rapidly water reaches the stream. In this sense, Fp is only represents half of the picture. The authors go on to create separate Fp's for each flow pathway, which is probably necessary for large catchments as each flow pathway likely do have large influences over space and time. However, this seems to be overcomplicating a model that was originally being created out of need for greater parsimony. If these pathway specific indices are necessary, then more discussion and justification is required in the text. The authors use vague language that needs some more clarification. Line 19 on page 7 contains "flow over a sufficiently long period". What is a sufficiently long period? Wouldn't a sufficiently long period wash out the "flashy" fluctuations that the authors are trying to explain with changing land cover/watershed degradation? If the 'sufficiently long period' is preventing what the study is attempting to explain, then I do not see how equation three could be derived. Maybe I'm missing something, but wouldn't the stochastic term represent all unexplained variations in the predicted river flow? Line 28 on page 7 explains that the stochastic term is equal to the sum of peak flows. Couldn't other unpredicted river flows have other anthropogenic origins that contribute to the river flow stochasticity (e.g. dam operations/failure, irrigation, urban water use, etc.)? The authors also mention new variables like Qadd and Fp,try without adequately discussing what they actually represent.

Point 3 Figures 2-9 were very readable and for the most part stand on their own, however the table were poorly formatted and vague. Table 1 does not provide land cover proportions by land cover type (other than forest). Percent developed land, existing flood control infrastructure, and population would all be helpful information. Not sure what 'dominant land cover' means. Do these watersheds have a history of damaging floods? Why were the parameters in table 2 chosen? The authors do not provide an adequate discussion of how these parameter values were estimated. Why were the defaults in GenRiver used for each of the land cover types in table 3? What process or methodology did GenRiver use to estimate these values? What does 'relative drought

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threshold' mean? The use of the word 'some' in table 4 is simply too vague when describing the scenarios. The reader is left wondering what the magnitude of change would be within each of these scenarios. All of the information in tables 1-4 are critical components of the GenRiver model. The legitimacy and accuracy of the model is weak without proper documentation and justification of the underlying model parameters. The authors must correct this if we are to have any confidence in the results. Table 5 and its corresponding discussion regarding the sample sizes required to reject a null hypothesis is interesting, but not enough information was given to make this section clear. The methodology is clear enough, but the implications were not really discussed. The statement beginning on line 21 on page 14: "In practice, that means that empirical evidence that survives statistical tests will not emerge, even though effects on watershed health are real" is vague and needs some more clarification. Lastly, in table 6, the authors provide broken links to the detailed reports of rainfall and river flow data. Moreover, there is very little discussion on the accuracy and metadata of each of these data sources, all of which have different origins.

Summary Overall, I think that this study addresses a critical knowledge gap with important implications. However, the conceptual foundation regarding watershed health and flow predictability requires a closer examination. The derivation of Fp and the process used to create the GenRiver model parameters needs more discussion, clarification, and justification if the reader is to have any confidence in the results. I think that if the authors were to accomplish these revisions then the paper would simply be too long and cover too much ground. Breaking the research into two separate papers is probably a better course with one focusing more on the conceptualization and creation of the Fp term and one on the application of it within the GenRiver framework.

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