

Interactive comment on “Strong increases in flood frequency and discharge of the River Meuse over the late Holocene: impacts of long-term anthropogenic land use change and climate variability” by P. J. Ward et al.

Anonymous Referee #2

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This is a well-written paper that aims at disentangling the respective role that human induced land use change and climate change have on the flood frequency of a medium-sized river basin over the timescale of several millenia. The applied methodology is in general sound and the results are discussed sufficiently well.

I do have some comments, however, which need to be addressed before acceptance.

1)First of all, the authors state that the forested area has been relatively stable over the last century (line 9 page 2524) and that therefore no land use changes were simulated

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within the 20th century (line 24 page 2537). On the other hand, the authors come to the conclusion that in the 20th century it has mainly been climate change that had an impact on flood frequency changes, and not land use change, which is contrary to their findings for the period 1000-2000 AD compared to 4000-3000 BP. Isn't this quite logic if land use is kept stable in model simulations ?? Furthermore, several studies by Petit & Lambin in 2002 in *Landscape Ecology, Global Change and Biology*, and Intern J GIS have illustrated that significant land use changes took place until the late 1950's in the Belgian Ardennes. It would be interesting to see what their impact on runoff was.

2) For the period 4000-3000 BP it is estimated that human impact on land cover was negligible. Compared to the present-day situation this may be true but it is not entirely correct. For instance, the paper by Henrard (2003; *The Mesolithic of the Ourthe Basin: landscape settlement and Neolithisation, L'Anthropologie*, 107: 615-644; sciencedirect.com) showed that many sites dating from the Late Mesolithic and early Neolithic period are known for the Belgian Ardennes Region. Humans certainly must have had any impact. Probably their impact was quite low but the assumption that the areas was 100% forest is not correct. Maybe there was a 5% deforestation rate at that time ? It would be interesting to see what this 5% of deforestation would have on runoff discharges and flood frequency. The relation between land cover and runoff is not-linear, the impact of deforesting the first 5% or the 5-10% will be different. For the Meuse basin, this differing impact is not known or discussed in the paper.

3) Related to comments 1 and 2, it would strengthen the paper if a sensitivity analysis is carried out whereby land use is changed with several %. For the moment, only a few model parameter values that translate a land use map into a runoff value were included in the sensitivity analysis (eg SWHC values) but the land use map itself has always been treated as correct. What would be the result if for a given time period the % forest and cropland is (for instance) not 45 and 25% respectively but 50 and 20% respectively ?? Such a sensitivity analysis could indicate whether the model needs very detailed land use maps or only robust indicators of land use and land use change.

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If a small change in land use has a large impact on runoff, then some of the initial assumptions and conclusions I referred to in comment 1 and 2 may not be valid.

4) One of the parameters in the model is the Soil water holding capacity of SWHC. I wonder if it is really necessary to take this parameter into consideration since its estimation is highly questionable: 1) there is a large uncertainty on the spatial distribution of soil characteristics, 2) there is a large uncertainty on the exact spatial distribution of land cover, 3) hence there is an even larger (too large ?) uncertainty on the relation between land cover and soil. Furthermore, the sensitivity analysis has shown that changes in SWHC hardly have any impact on modelled runoff discharges. I therefore suggest to leave this parameter out of the model and work with one constant value. This would reduce model complexity seriously without losing much information (see eg Van Rompaey and Govers, Int J GIS 2002).

5)The authors state that simulated PE corresponds well with observed (or estimated) PE (line 2-3 page 2532). However, I think the discrepancy between both values (605 vs 555 mm.yr) is not insignificant. Given that annual rainfall equals 950 mm/yr , this means that simulated runoff equals $950-605= 345$ mm/yr. However, using estimated PE values, annual runoff would be 395 mm/yr, which is almost 15% higher than simulated. One of the conclusions is that during the period 1000-2000 AD, mean runoff is 6% higher than for the period 4000-3000 BP. How should we compare both values ? Is the calculated difference in runoff for both periods significant enough if one compares this to the model error on PE-values ?

6) In the discussion and also in table 2, the period 4000-3000 BP is compared to the period 1000-2000 AD and to the 20th century. Given that the direction of the trend in runoff is different for the 20th century, it would be very interesting to see what the average and frequency distributions of runoff discharge are for the period 1000-1900 AD. As it discussed right now, the period 1000-2000 AD is not homogeneous and thus the influence of land use change and climate change will be different if one analyses the period 1000-1900 AD separately. Including the 20th century means that opposite

trends in PE and discharge are partly counterbalanced (see figure 4). As a result, the variability in the period 1000-2000 AD is much larger than for the period 4000-3000 BP as is concluded on page 2534 line 13, however, at that stage the authors come up with a different explanation for this higher variability.

7) one smaller comments: Line 25-27 page 2528: what is the unit of the crop value ? which equation is used to translate crop values into runoff rates ?

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