Response to Dr G. Di Baldassarre (Referee)

We thank Dr G. Di Baldassarre for his positive and constructive comments. Our responses for the revision of the manuscript are provided below in bold.

I have really enjoyed reviewing this paper that aims to develop human-nature modelling for flood protection investments. The paper is well written and the authors showed a wide knowledge of the scientific literature. I found the first part of the paper outstanding with a nice review of coupled modelling. I agree with the authors about the potentials of CHANS modelling. Indeed, a better understanding of the interactions and feedbacks between socio-economic and hydrological processes is definitely needed to advance the science of flood risk (Sivapalan et al., 2012, Bloeschl et al., 2013, Di Baldassarre et al., 2013). However, I have two major comments related to the (possibly apparent) lack of a consistent story linking the first and last part of the paper (focusing on coupled human and natural systems and proposing agent based modelling as a possible way out) with the example application (relating the performance of proactive/reactive approaches and the persistence of annual maximum floods) that is based on stochastic flood model and cost benefit analysis (sections 4 and 5).

My first comment is about the stochastic flood model (Section 4). ARMA(1,1) model is used to generate time series of annual maximum floods. The simple structure of the model is appropriate, in my opinion, because of the goal of this exercise. However, I think that using this approach may potentially result contradictory with the focus on fully coupled natural and human systems. In particular, the stochastic flood model simulating the natural system is not fully coupled with the human system. In particular, this model cannot simulate how human activities change the statistical properties of annual maximum floods (e.g. urbanization, land-use change, e.g. Brath et al., 2006) as well as the probability of flooding (e.g. flood protection structures, e.g. Di Baldassarre et al., 2009). The main goal of using coupled modelling in flood risk studies is the ability to simulate how the magnitude and frequency of floods shape human societies, while (in turn) human societies alter the magnitude and frequency of floods. In this study, only one side of these complex interactions and feedbacks is explored as the magnitude and frequency of floods are not directly altered by human interventions and simulated as a purely natural processes.

The outcome of the coupled modelling in this case is the level of protection which is optimal based on a Cost-Benefit criterion which does alter the flood magnitude / frequency relationship at the point of impact by virtue of the level of protection chosen through the B-C analysis. However, we do agree that the 'natural' flood magnitude / frequency relationship can be changed due to human activities, and we have not accounted for this in our analysis, nor have we accounted for the growth in vulnerability that occurs over time once a community perceives that they are protected in the classical flood protection approach – yet another human-natural system interaction.

Understanding and quantifying the impacts of changes in land use management and urbanisation on flooding remains a major challenge in hydrology (e.g. O'Connell et al., 2007; Robson et al., 2002). Drivers for change are typically external to the catchment and hence may need the inclusion of additional actors in the agent-based model, e.g. national or EU agricultural policies (Hall et al., 2003, Matthews et al., 2007). This is an additional level of complexity that we have not attempted in the modelling. We believe that to incorporate these additional issues into the framework would significantly expand an already ambitious research agenda. However, in the

revised manuscript we propose to include paragraphs on modelling the impacts of land use changes on the flood-magnitude frequency relationship, and on agent-based modelling of the drivers of land use change.

REFERENCESTO BE ADDED

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The second comment is related to the use of cost and benefit analysis (Section 5). Indeed, it has been often hypothesized that "societies react and adjust to a changing environment pursuing the maximization of their benefits or minimizing the (perceived) costs. However, defining cost and benefit functions of people is difficult as decision making is often a balance of multiple, conflicting objectives, and the attitude towards risk and uncertainty can strongly vary across human societies" (Di Baldassarre et al., 2013) depending on political and socio-economic conditions as well as cultural values (Eiser et al., 2012; Wachinger et al., 2012, Scolobig et al., 2012). The limitations of cost benefit analysis are also recognized by the authors, who, in fact, eventually proposed the use of ABM framework. But, then, one may wonder (as also mentioned by the first Referee) why there is an entire section dedicated to the development of an exercise based on cost and benefit analysis, while the ABM framework is only mentioned at the end of the paper without an example application.

In section 5 we have assumed that Cost-Benefit economic utility dominates over social and ecological aspects, based on recent experiences in the UK (Johnson et al., 2007). Although the approach taken is a simplification, we do feel that it provides some insight into the relative merits of the Proactive and Reactive Strategies. However, we recognise that C-B Analysis is but one component of a sustainable approach to flood risk management that must embrace environmental and social objectives, and that there are conflicts to be resolved between the economic, social and environmental objectives.

In response to the Reviewer's comments (and those of Reviewer 1), section 5 will be made more concise in the revised manuscript. To provide balance, a new section will be added towards the end of the manuscript discussing the relative merits of the cost-benefit and agent-based approaches, emphasizing further that the latter approach can help stakeholders with specific objectives in recognizing the positions of other stakeholders with conflicting objectives and hopefully arriving at a consensus. The main aim of the C-B approach was to explore, in the first instance, the relative merits of Proactive and Reactive Strategies in an increasingly variable

climate, before tackling the bigger challenge of assessing these strategies where the decision-making process is much more complex and involves multiple stakeholders.

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