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Natural Hazards and Earth System Sciences
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Discussions

Interactive comment on "Regional prioritisation of flood risk in mountainous areas" *by* M. C. Rogelis et al.

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We would like to thank the anonymous referee for the thorough and constructive review of the manuscript. We have carefully considered the comments, and through this document would like to provide a detailed response to each, as well as how we have adapted the manuscript where applicable.

GENERAL COMMENTS

The paper lacks a clear description of the aim and subsequently achieved results in this case study. For the reviewer it is not clear, why this analysis is carried out and what the new achievements of this research are.

The paper lacks a clear structure of the aims of this study, the current state of knowledge in the literature and following the specification of research goal(s).

The results are discussed, but not reflected in the sense which new insights are achieved against earlier studies.

Some results are mixed with an earlier publication (Rogelis and Werner, 2013) at the end of the paper, which are however not incorporated and discussed in previous sections.

The discussion does not cover a critical discussion of the limitations of this approach and, if applicable, recommendations for future research. For example, the choice of three classes – high, medium and low – of course leads to a low sensitivity of the results with respect to the choices on the input data. However, choosing a 5-step scale or a continuous representation of the results might be far more supportive for management.

Particularly the length of the paper (too long) and its writing style in the abstract and the conclusion using an unnecessary short form of writing (too short) leads to significant limitations in the readability of the text and thus, its understanding.

The provision of figures in grey-scale also limits the readability of the fig-

ures unnecessarily too. Thus, in general, I recommend the publication after major modifications of both text and tables / figures.
RESPONSE:
The description of the aim and results was improved along the paper, particularly in the introduction and the conclusions. The structure of the paper was improved according to the specific comment provided by the reviewer. The analysis against earlier studies was included in the discussion section. In the reviewed version of the paper thee results of the earlier publication (Rogelis and Werner, 2013) are only used as input for the analysis and were deleted from the discussion. Limitations and need of future research were included in the discussion section. The writing style was reviewed. The figures were improved and presented in colour.

SPECIFIC COMMENTS

1. **All figures (and tables, if applicable) should be provided in full colour. All figures and maps should contain the key elements of scientific visualisations, i.e. scale and north arrow (mainly done) and legend (not available in some figures, particularly Figure 9, which is the key figure of this paper.**
   RESPONSE: We agree that the figures should be in full colour. These were improved and are now presented in colour; special care was taken with the scales, north arrows and legends.

2. **The writing style is in some sections to short and thus leads to a limitation of the readability of the text.**
   RESPONSE: The writing style of the paper was reviewed and changes were introduced to improve the readability.

3. **If variables or indicators are mentioned in the text, e.g. lack of rescue personnel, a different typeset (italic, bold) should be used in order to support the reader to distinguish between the text and the (list of) indicators.**
   RESPONSE: We agree that typesetting the name of the variables in italic helps to clarify the text; therefore they are now presented in italic.

4. **The names of all variables and indicators used in the paper have to be consistent (particularly with respect to Figure 2). The author uses different terms for the same indicators, which leads to significant problems of the understanding of the text.**
   RESPONSE: Both the tables and the text were reviewed, and the names of all variables was made consistent.

5. **The author should make use of consistent numbering [e.g. (i)-(iv)] or bullet points in numerous sections, when longer lists of parameters / variables are presented. Otherwise, these parameters should be described in a table instead of the text.**
   RESPONSE: Numbering and bullets were included. We have also improved the consistency between the use of numbers and of bullets.

6. **The literature review seems to be good, but lacks a concise summary of the most relevant terms and the definition chosen for this paper. If currently is a long list of definitions found in the literature, but to the reviewer it is not clear which terms are finally relevant for this paper.**
   RESPONSE:
   We have improved the literature review, also in response to the comments of reviewer 1. To clarify the definitions used in the paper, we have added added these at the end of section 2.

7. **The conclusions are too unspecific. See also the evaluation of the paper above. It is unclear what were the contributions, the new findings, the need**

for further research. Revision required.
RESPONSE:
We have improved the conclusions to underline what we see as the contributions of this paper. We have also added our vision on future research directions.

Specific comments (in the order of the paper) (page | line) Abstract

8. **4266 | 11: four constituents are mentioned, but in the text there are only three: (i) socio-economic fragility, (ii) lack of resilience, and (iii) physical exposure. Rephrasing required.**
RESPONSE:
The reviewer is right. The sentence has been changed as follows:

Results show that the components of vulnerability can be expressed in terms of three constituent indicators; (i) socio-economic fragility, which is composed of demography and lack of well-being; (ii) lack of resilience and coping capacity, which is composed of lack of education, lack of preparedness and response capacity, lack of rescue capacity, cohesiveness of the community; and (iii) physical exposure is composed of exposed infrastructure and exposed population.

1 Introduction

9. **4267 | 15: *"However, more holistic approaches go further than including just physical vulnerability and incorporate social, economic, cultural and educational aspects, which are in most cases the cause of the potential physical damage (Cardona, 2003).*" Why is this the case and/or required. Further explanation required.**
RESPONSE:
We have added further explanation to clarify the motivation for the more holistic approaches:

A risk analysis consists of an assessment of the hazard as well as an analysis of the elements at risk. These two aspects are linked via damage functions or loss models, which quantitatively describe how hazard characteristics affect specific elements at risk. This kind of damage or loss modelling, typically provides an estimate of the expected monetary losses (Seifert et al., 2009; Luna et al., 2014; van Westen et al., 2014; Mazzorana et al., 2012). However, more holistic approaches go further, incorporating social, economic, cultural, institutional and educational aspects, and their interdependence (Fuchs, 2009). In most cases these are the underlying causes of the potential physical damage (Cardona, 2003; Cardona et al., 2012; Birkmann et al., 2014). A holistic approach provides crucial information that supplements flood risk assessments, informing decision makers on the particular causes of significant losses from a given vulnerable group and providing tools to improve the social capacities of flood victims (Nkwunonwo et al., 2015). The need to include social, economic and environmental factors, as well as physical in vulnerability assessments, is incorporated in the Hyogo Framework for Action and emphasized in the Sendai Framework for Disaster Risk Reduction 2015-2030, which establishes as a priority the need to understand disaster risks in all its dimensions (United Nations General Assembly, 2015). However, the multi-dimensional nature of vulnerability has been addressed by few studies (Papathoma-Kohle et al., 2011).

10. **4268 | 26: *" or even creating new hazards"*: The statement is unclear. How can human actions increase the hazard? The hazard is, according to the reviewers understanding, a natural process. Human actions can only have influence of the propagation of the hazard, not the hazard itself. Rephrasing required.**
RESPONSE:
Hazard is defined by the UN/ISDR as "a potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property

damage, social and economic disruption or environmental degradation. Hazards can include latent conditions that may represent future threats and can have different origins: natural (geological, hydrometeorological and biological) or induced by human processes (environmental degradation and technological hazards). Hazards can be single, sequential or combined in their origin and effects. Each hazard is characterised by its location, intensity, frequency and probability." (http://www.unisdr.org/2004/wcdr-dialogue/terminology.htm)

According to the above definition, hazards can be caused by human activity (human-induced hazards) and natural hazards can be exacerbated by human activities. In order to clarify this point, a sentence giving an example was added, as follows:

Vulnerability is closely tied to natural and man made environmental degradation at urban and rural levels (Cardona, 2003; UNEP, 2003). At the same time the intensity or recurrence of flood hazard events can be partly determined by environmental degradation and human intervention in natural ecosystems (Cardona et al., 2012). This implies that human actions on the environment determine the construction of risk, influencing the exposure and vulnerability as well as enhancing or reducing hazard. For example, the construction of a bridge can increase flood hazard upstream by narrowing the width of the channel, increasing the resistance to flow and therefore resulting in higher water levels that may inundate a larger area upstream.

11. **4269 | 6 *"The consequence of the interaction between hazard and vulnerability in the context of small watersheds is that those at risk of flooding themselves play a crucial role in the processes that enhance hazard."* This statement is fully unclear to the reviewer. Remark is related to the comment above.**
    RESPONSE:
    To help clarify, the paragraph was modified as follows:

The consequence of the interaction between hazard and vulnerability in such small watersheds is that those at risk of flooding themselves play a crucial role in the processes that enhance hazard, through modification of the natural environment. Unplanned urbanization, characterized by a lack of adequate infrastructure and socioeconomic issues (both contributors to vulnerability) may also result in severe degradation, which increases the intensity of natural hazards (UNISDR, 2004). In the case of floods, such environmental degradation may lead to an increase in peak discharges, flood frequency and sediment load.

12. **4269 | 9: *"This paper aims at the prioritisation of watersheds, which can be interpreted as a proxy for flood risk assessment, thus providing guidelines for the managing of those risks."* Again unclear. What is meant specifically?**
    RESPONSE:
    The sentence was modified as follows:

    In this paper a method to identify montane watersheds with the highest flood damage potential at the regional level is proposed. Through this, the watersheds to be subjected to more detailed risk studies can be prioritized in order to establish appropriate flood risk management strategies. The method is demostrated in the montane watersheds that sur- round the city of Bogota ÌĄ (Colombia), where floods typically occur as flash floods and debris flows.

13. **4269 | 25+26: A uniform use of the terms Section and Sect. is proposed. The reviewer suggests to use the full term Section in ln26 in order to enhance the readability of the paper.**
    RESPONSE:
    Sect. was replaced by Section throughout.

14. **4269 | 27: numbering of the list of aspects strongly required.**

15. ***"Section 4 presents the exposure areas obtained through the simplified methods; the results of the principal component analysis in terms of a socio-economic fragility indicator, a lack of resilience indicator and a physical exposure indicator; the overall vulnerability indicator obtained from the combination of the socio-economic fragility, lack of resilience and physical exposure indicators; the sensitivity analysis of the vulnerability indicator; and the prioritization of watersheds according to the qualitative risk indicator and comparison with damage records."*** **Is this one sentence? Numbering, listing or another form of structuring is required here. The reviewer suggests to rather guide the reader which aspect is related to which one, what is presented subsequently, following, instead of providing a pure list of terms, which do not add value to the text. Furthermore, highlight the indicators with a different typeset, as proposed earlier.**
RESPONSE:
Attending both comments, the paragraph was modified as follows: *The paper is structured as follows: (i) Section 2 reviews the conceptual definition of vulnerability as the foundation of the paper; (ii) Section 3 describes the study area, and the data and methodology used; (iii) Section 4 presents the results of the analysis. This includes the construction of the indicators and the corresponding sensitivity analysis, as well as the prioritisation of watersheds; (iv) Section 5 interprets the results that lead to the final prioritisation; (v) The conclusions are summarised in Section 6.*

2 Conceptualization of Vulnerability

16. **4270 | 19: Temporality seems to be the wrong term here, if the temporal dimension is meant. Rephrase.**
RESPONSE:
The section was restructured and as suggested by the other reviewer this sentence was deleted.

17. **4273 | 1:** ***". . .risk and is non hazard dependent; and lack of resilience to cope and recover, which is also defined as soft risk and is non hazard dependent."*** **To the reviewer it is not clear why resilient is not hazard depended. The intensity of the hazard has indeed a huge impact on the resilience of the socio-economic system.**
RESPONSE:
We agree with the reviewer that the classification of lack of resilience to cope and recover as strictly non hazard dependent is controversial. In fact, there are different interpretations of the term. We consider that the following definition is the one that best fits the framework of the paper:
Lack of resilience and coping capacity: limited capacities to cope or to recover in the face of adverse consequences (Birkmann, 2014).

This definition of resilience also implies that the respective system or unit is able to adapt and learn, meaning that the system –e.g. social system, ecosystem or coupled human–environmental system –can mobilise sufficient self-organisation to maintain essential structures and processes within a coping or adaptation process. This definition implies that knowledge and organization are important components of resilience. In the analysis they are measured by level of education, illiteracy, access to information, robberies, participation, infrastructure/accessibility, hospital beds, health care resources and rescue personnel. However, there are two indicators that are hazard dependent. These are: (i) risk perception and (ii) early warning that relate to the type of hazard.
To address this comment the paragraph has been modified as follows:

In this study, physical exposure (hard risk and viewed as being hazard dependent), socioeconomic fragility (soft risk and is non hazard dependent) and lack of resilience and coping capacity (soft risk and is mainly non hazard dependent)

(Cardona, 2001) are used to group the variables that determine vulnerability in the study area. In this paper, the risk perception and the existence of a flood early warning, which are hazard dependent, are considered as aspects influencing resilience since they influence the hazard knowledge of the communities at risk and the level of organization to cope with floods.

3 Methods and Data

3.1 Study area

18. **4273 | 17: *"Eighteen percent of the urban area has been occupied by informal constructions, housing almost 1 400 000 persons. This is some 22 % of the urban population, corresponding to some 3 700 000 dwellings (Pacific Disaster Center, 2006)."* The reviewer does not understand why less people are living in more houses (ratio 1:3). Rephrase or explain.**
    RESPONSE:
    We apologise for the confusion. The number of houses reflects the total number of houses in the city of Bogotá. To avoid the confusion the sentence was modified as follows: *Eighteen percent of the urban area has been occupied by informal constructions, housing almost 1 400 000 persons. This is some 22 % of the urban population of Bogotá (Pacific Disaster Center, 2006).*

19. **4273 | 24: *"The start of the urbanization of the mountainous area of the Tunjuelo River basin occurred in the 60s and 70s."* Informal writing. Rephrase 60s and 70s.**
    RESPONSE:
    The sentence was deleted since it is redundant with the first sentence that indicates that *"Between 1951 and 1982, the lower (northern) part of the Tunjuelo basin was the most important area for urban development in the city."*

20. **4274 | 1: *"The most damaging floods in the Tunjuelo basin have caused significant economic losses and fatalities (DPAE, 2003a, b)."* This statement is far too unspecific and needs further explanation.**
    RESPONSE:
    This sentence was deleted and a table presenting information on the number of watersheds and recent flooding events was added.

21. **4274 | 3: *"The urban development of the watersheds located in the hills to the east of Bogota (see Fig. 1) has a quite different characteristic to that of the Tunjuelo basin."* Different characteristics in which sense? Be more specific and describe the characteristics, if they are relevant for the paper, or remove the statement, if it has no relevance.**
    RESPONSE:
    The sentence was modified as follows: *The urban development of the watersheds located in the hills to the east of Bogota (see Figure1) has a different characteristic to that of the Tunjuelo basin. Not only has this taken place through both informal settlements, but also includes exclusive residential developments (BuendÄśa, 2013). In addition, protected forests cover most of the upper watersheds.*

3.2.1 Delineation of exposure areas

22. **4275 | 2: Define clear water floods. The term is unknown to the reviewer.**
    RESPONSE:
    The following paragraph was added at the beginning of Section 3.2.1: *Flood events in the watersheds considered in this study typically occur as flash floods given their size and mountainous nature. Flash floods in such small, steep watersheds can further be conceptualized to occur as debris flows, hyperconcentrated flows or clear water flows (Hyndman and Hynd- man, 2008; Jakob et al., 2004;*

Costa, 1988). Costa (1988) differentiates: (i) clear water floods as newtonian, turbulent fluids with non-uniform concentration profiles and sediment concentrations of less than about 20% by volume and shear strengths less than 10 N/m2; (ii) hyperconcentrated flows as having sediment concentrations ranging from 20 to 47% by volume and shear strengths lower than about 40 N/m2;and (iii) debris flows as being non-Newtonian visco-plastic or dilatant fluids with laminar flow and uniform concentration profiles, with sediment concentrations ranging from 47 to 77% by volume and shear strengths greater than about 40 N/m2. Debris flow dominated areas can be subject to hyperconcentrated flows as well as clear water floods (Larsen 390 et al., 2001; Santo et al., 2015; Lavigne and Suwa, 2004), depending on the hydroclimatic conditions and the availability of sediments (Jakob, 2005), and occurrence of all types in the same watersheds has been reported (Larsen et al., 2001; Santo et al., 2015). Therefore, the areas exposed to clear water floods and debris flows were combined. This provides 450 a conservative delineation of the areas considered to be exposed to flooding.

23. **4276 | 1: The whole section is very technical and more suitable for a technical appendix, as it does not support the understanding of the paper and has no relevance for the discussion of the results. The reviewer suggests to shorten the text on page 4276 significantly or move the section to the appendix.**
    RESPONSE:
    The text describing the methods has been shortened as proposed.

24. **4276 | 22: This paragraph has no added value at this very place. Move it to the part, where the verification is described (4.6.?)**
    RESPONSE:
    We thank the reviewer for the thoughtful comment, but do consider that the explanation on the method used to validate the delineation of the exposure areas does fit correctly in section "3.2.1 Delineation of exposure areas". In the subse-

quent subsections of the methodology the focus is placed on the indicators as also in section "4.6 Prioritization of watersheds according to the qualitative risk indicator and comparison with damage records". We think that mixing indicators and exposed areas would be confusing.

3.2.2. Choice of indicators and principal component analysis for vulnerability assessme

25. **4277 | 3: *"The complexity of vulnerability requires a reduction of available data to a set of important indicators that facilitate an estimation of vulnerability (Birkmann, 2006)."* This statement is contrary to earlier statements of the author. In the introduction the method is presented to be suitable for data-sparse applications, now available data is reduced. This needs further explanation and/or rephrasing.**
    RESPONSE:
    We agree that the sentence can be confusing. The word reduction is probably not the best here; therefore the sentence was modified as follows: *The complexity of vulnerability requires a transformation of available data to a set of important indicators that facilitate an estimation of vulnerability (Birkmann, 2006).*

26. **4277 | 15: *"The three spatial levels considered are block, watershed and locality, where the locality corresponds to the 20 administrative units of the city."* What means block?**
    RESPONSE:
    Block was replaced by "urban block" for more clarity. *The three spatial levels considered are urban block, watershed and locality, where the locality corresponds to the 20 administrative units of the city.*

27. **4278 | 12: The last two paragraphs double in the sense, that some aspects are described twice. It is required to merge the sections accordingly.**

RESPONSE:
We would like to ask for further explanation on this comment. The paragraph corresponding to 4278-12 explains how PCA is applied in the case of resilience. The two paragraphs before that, relate to the explanation of Figure 2 and the explanation of the PCA methodology. It is not clear to the authors what aspects are described twice.

28. **4249 | 8: Merge the paragraphs with Figure 2, as this would support the understanding of Figure 2 and reduce the length of the text.**
RESPONSE:
The paragraphs form 4278-25 to 4279-7 were merged with figure 2.

3.2.3 Sensitivity of the vulnerability indicator

29. **4280 | 9: *"(the Scree test acceleration factor, optimal coordinates, the Kaiser's eigenvalue-greater-than-one rule and parallel analysis)"* Do not repeat the list of items, but reference to the earlier section where these where mentioned. This also applies for two later parts of the text, where this list is repeated unnecessarily.**
RESPONSE:
The list of terms was deleted and references to the previous text included.

3.2.4 Categories of recorded damage in the study area

30. **4280 | 26: *"Enough data for the analysis of flood events in 14 watersheds was collected."* Subjective statement. Rephrase. What is enough?**
RESPONSE:
The sentence was changed as follows to be clearer what was intended. However, please note that section 3.2.4 was significantly modified to increase clarity on the method used to classify the watersheds according to damage.

Complete records were only available for 14 watersheds.

31. **4281 | 8: *"A score of 0 implies that no flood damage has been recorded in the watershed for a flood event, despite the occurrence of flooding, while a score of 10 corresponds to watersheds where human losses or serious injuries have occurred."* How has this been done. Does the classification follow an accepted methodology, such as the Multi-Coloured-Manual or any other reference?**
RESPONSE:
We would like to thank the reviewer for the suggestion of the Multi-Coloured-Manual. However, the methodology described in this reference refers to the assessment of economic losses and requires data that are not available for the study area. In the study area the impacts of flooding have been described only in terms of date, location, injured people, human losses, evacuated people, number of affected houses and indication whether the flood depth was higher than 0.5 m or not (information on the inundation depth at property level is not available). Data on the particular characteristics of the properties that have been flooded are not available (type of structure, areas, heights, depth/damage data, damage to structures, damage to household inventories, clean-up costs, evacuation costs etc). The limitations on data prevent the calculation of the value of damages. Therefore we proposed a methodology based on the available, in which impacts are sorted according to pre-established criteria. In order to clarify the method, section 3.2.4 was modified as follows:

A database of historical flood events compiled by the municipality was used to classify the watersheds in categories, depending on damages recorded in past flood events. For each of these events the database includes: date, location, injured people, human losses, evacuated people, number of affected houses and an indication of whether the flow depth was higher than 0.5 m or not. Unfortu-

nately, no information on economic losses is available and as the database only covers the period from 2000 to 2012 it is not possible to carry out a frequency analysis. Complete records were only available for 14 watersheds. The event with the highest impact for each watershed was chosen from the records. Subsequently, the 14 watersheds were ordered according to their highest impact event. The criteria to sort the records and to sort the watersheds according to impact from highest to lowest were the following (in order of importance):
1. Human losses
2. Injured people
3. Evacuated people
4. Number of affected houses
Watersheds with similar or equal impact were grouped, resulting in 11 groups. The groups were again sorted according to damage. A score from 0 to 10 was assigned, where a score of 0 implies that no flood damage has been recorded in the watershed for a flood event, despite the occurrence of flooding, while a score of 10 corresponds to watersheds where human losses or serious injuries have occurred (see Table 3). The 11 groups were further classified into three categories according to the emergency management organization that was needed for the response: (i) low: the response was coordinated locally; (ii) medium: centralized coordination is needed for response with deployment of resources of mainly the emergency management agency; (iii) high: centralized coordination is needed with an interistitutional response. This classification was made under the assumption that the more resources are needed for response the more severe the impacts are, allowing in this way a comparison with three levels of priority classification.

32. **4281 | 9: *"The watersheds were subsequently divided into high, medium and low categories of flood impacts based on three equal intervals of the score range."* Show this classification also in Table 1.**

RESPONSE:
The categories were included in table 1.

3.2.5 Prioritization of watersheds

33. **4281 | 27: *"Under this procedure the resulting matrix corresponds to the best fit of the priority and the classification according to damage scores from flood records."* The statement is unclear to the reviewer. Rephrase.**
RESPONSE:
The paragraph was rephrased as follows:

In order to combine the vulnerability and susceptibility to derive a level of risk, a classification matrix was used. This is shown in figure 2. The columns indicate the classification of the vulnerability indicator and the rows the classification of the susceptibility indicator. Only two priority outcomes are well defined, these are the high and low degrees assigned to the corners of the matrix corresponding to high susceptibility and high vulnerability and low susceptibility and low vulnerability (cells a and i), since they correspond to the extreme conditions in the analysis. The priority outcomes in cells from b to h were considered unknown and to potentially correspond to any category (low, medium or high priority). To define the category for these cells, the priority using all possible matrices (all possible combinations of categories of cells b to c) was assessed for the watersheds for which flood records are available. Once, these watersheds were prioritised, a contingency table is constructed comparing the priority with the damage category (from table 3) from which the "proportion correct" is obtained. The classification matrix that results in the highest proportion correct (best fit) was used for the prioritisation of the whole study area.

4 Results

34. **4282 | 21: *"(height above the stream level of 1, 2,3, 4, 5, 7 and 10 m)"* Repetition. Reference instead of repeating this.**

RESPONSE:
The sentence was modified as follows:

The buffers that were obtained by applying the criteria explained in Section 3.2.1, were compared with the available flood maps.

35. **4284 | 6: "These resulted in 1, 2, 2 and 3 components to be retained respectively." Unclear what is meant here. Where does this list of numbers refers to?**
RESPONSE:
The sentences presenting the results of the different methodologies to define the number of principal components are not important. Therefore, to avoid confusion the sentence was deleted from paragraphs in sections 4.2 and 4.3 as follows:

4.2 Socio-economic fragility indicators

The results of the principal component analysis applying a varimax rotation are shown in table 3. Two principal components were retained as this allowed a clear interpretation to be made for each of the components. ...

4.3 Lack of Resilience and coping capacity indicators

The loadings of the indicators representing lack of resilience and coping capacity obtained from the PCA are shown in table 4. Two principal components were used; ...

36. **4284 | 20: Harmonize the order of the terms in the equations with the order of the table, or the other way around.**
RESPONSE:
The terms in the equations were harmonized as suggested.

37. **4284 | 5: Repetition!**

RESPONSE:
The paragraph was modified as shown in response to comment 28.

38. **31. 4284 | 6: See comment above. Unreadable.**
RESPONSE:
The paragraph was modified as shown in response to comment 28.

39. **4284 | 16: Other terms are used in Figure 2. Harmonize.**
RESPONSE:
The terms in the paper were made consistent with figure 2.

40. **4287 | 18: Add this description in a legend of Figure 9 instead of a description in the text.**
RESPONSE:
The legend to figure 9 was extended with the description.

41. **4288 | 17: A reference to Figure 4 (white arrows, correct?) seems possible and is thus proposed.**
RESPONSE:
A reference to figure 4 was added. The arrows are correct, as they show the direction towards which the flow extends.

42. **4288 | 25: It is unclear to the reviewer where the term buffers refers to.**
RESPONSE:
A reference to Figure 4-c was added to clarify where the buffers can be visualized.

43. **4289 | 12: The term strata, used frequently in the paper, needs further explanation.**
RESPONSE:
In order to clarify the definition of strata, an improved definition was included in figure 2.

5 Discussion

5.2 Representativeness and relative importance of indicators

44. **4290 | 5: The paragraph introduces new facts on physical exposure, which should have done far earlier in the text. The whole paragraph should be put to the literature review, to be referenced for discussion, instead of introducing new aspects to the paper. Major revision of this section required.**
RESPONSE:
The paragraphs describing physical vulnerability were deleted.

5.3 Sensitivity of the vulnerability indicator

45. **4292 | 1: How relevant is this discussion, if only three classes are shown? How would the results look like with 5 or more classes? Substantial improvement of the discussion required.**
RESPONSE:
Subsection 5.3 was restructured as follows:

The interquartile ranges cross the thresholds between categories of low, medium and high vulnerability only in the case of 13 watersheds (see figure 8). This means that only these 13 watersheds are sensitive to the criteria selected for the analysis. In 11 of these, the category changes between medium vulnerability and high vulnerability and in the remaining two the change is from low to medium vulnerability. Watersheds with values of the vulnerability indicator out of the intermediate ranges of the thresholds are robust to the change in the modelling criteria. Clearly, these results are dependent on the number of categories. While introducing more categories may provide more information to differenciate watersheds, the identification of category of the watersheds may become more difficult due to the sensitivity to the results. Therefore, in order to preserve identifiability

of the vulnerability category of the watersheds more than three categories could not be used. However, indicator-based regional studies that classify vulnerability in 3 categories, have shown to provide useful information (Kappes et al., 2012; Liu and Li, 2015; Luino et al., 2012)..
The impact on the proportion correct of a shift of category for the 13 watersheds mentioned above can only be assesssed for the 2 watersheds where flood records are available. This does not result in changes in the contingency matrix shown in figure 6-b. With respect to the assigning the priority to the watersheds, only 7 (7% of the total) of the 13 watersheds that showed sensitivity to a shift of the vulnerability categories were found to be sensitive to a change in priority (high/medium), which reflects the robustness of the analysis using the considered categories.

5.4 Interrelations between susceptibility and vulnerability in the prioritization indicator

46. **39. 4292 | 24: land cover indicator: A completely new aspect is introduced, which is not shown in earlier sections / tables / figures. To the reviewer is unclear how this relates to the overall results of the paper. Major revision of the paper concerning this aspect might be required, if the aspect is assessed to be relevant for the paper by the author.**

47. **4293 | 10: The comment above is applicable.**

RESPONSE:
Section 5.4 was restructured and the discussion on the land cover was removed from the paper so that the focus is kept in the vulnerability and prioritisation.

48. **4293 | 21: New literature is introduced. Re-order the paper and add the literature to the first sections.**

RESPONSE:
Section 5.4 was restructured and the new literature was removed.

49. **4294 | 14: "On the other hand, the priority classification shows watersheds in medium and high priority that do not have flood damage records, this highlights the complexity of the comparison since the non-occurrence of flood damage in the last ten years does not mean that it cannot occur in the future." This remark is obsolete and should be revised, also at a later section of the paper.**
RESPONSE:
The sentence was deleted and Section 5.4 was restructured.

6 Conclusions

50. **4295 | 25 *"The methodology used in this paper allows a rapid assessment and prioritisation of regional flood risk based on available information in a developing mountainous city."* This method is, according to the reviewers evaluation, not suitable for rapid assessments, as this term is used in another way in the field of flood risk management. If the author believes in a contribution in the field of rapid assessments, the author should provide a review of existing methods and definitions of rapid assessments earlier in the paper. Otherwise, revise this statement and do not add new aspects to the paper at the very end.**
RESPONSE:
The terms "rapid assessment" were deleted to avoid confusion.

51. **4296 | 1: The paragraph is fully unclear to the reviewer and too unspecific. Rephrasing required.**
RESPONSE:
The conclusions were reviewed and the sentence was deleted.

Further comments (in the order of the paper) (page | line)

52. 4266 | 14: exposure is → exposure which is

    RESPONSE: the correction was included

53. 4267 | 25: constitute – is this the correct word? The sentence does not make sense.

    RESPONSE: constitute was replaced by "are"
    The importance of indicators is rooted in their potential use for risk management since they are useful tools for identifying and monitoring vulnerability over time and space, for developing an improved understanding of the processes underlying vulnerability, for developing and prioritising strategies to reduce vulnerability, and for determining the effectiveness of those strategies (Rygel et al., 2006)

54. 4242 | 8: "Authors such as Vogel and O'Brien (2004) as cited by Birkmann (2006) stress the fact that vulnerability is;" replace ; by : and number or bullet the items.
    RESPONSE: The sentence was deleted as a result of the modification of the section.

55. 4272 | 20: "Hence, if population and economic resources were not located in (exposed to) potentially dangerous settings, the problem of disaster risk would not exist." ADD or before exposed, reading: (or exposed to)

    RESPONSE: The sentence was deleted as a result of the modification of the section.

56. 4273 | 1: non hazard dependent → not hazard dependent (twice!)

    RESPONSE: The sentence was deleted as a result of the modification of the section.

57. 4273 | 6: 2640 ma.s.l.: abbreviation requires an introduction
    RESPONSE: “m.a.s.l” was replaced by “meters above sea level”

58. 4277 | 9: “according to literature” ADD the, reading “according to the literature”

    RESPONSE: the word “the” was included.

59. 4279 | 3: “relevant aspects” ADD as, reading “relevant as aspects” or “as relevant aspects”

    RESPONSE: this sentence was deleted and merged with figure 2.

60. 4281 | 25: “Proportion correct” seems to be a standing term in this paper. Highlight this by “” or any other means, as it otherwise should read “correct proportion”.

    RESPONSE: “” were added.

61. 4286 | 10: add , before where (twice) or shorten / split sentence.

    RESPONSE: the paragraph was modified as follows:

    The demographic conditions are more variable, showing low values (or better conditions) in the watersheds in the South, where the land use is rural. Low values also occur in the North, where the degree of urbanization is low due the more formal urbanization processes (see figure 5-a).

62. 4287 | 19: combination: plural required. reading “combinations of choices”

    RESPONSE: The sentence was deleted as a result of the modification of the section.

63. 4292 | 11: ADD the, reading “reflect the robustness in the analysis”

    RESPONSE: The word “the” was included.

64. 4296 – all references: What mean the numbers behind all references, e.g. the 4290 behind the first reference? Did something went wrong with the citation software? Check and revise all references.
    RESPONSE: The document was submitted in LATEX using the standard template for preparing papers in NHESS, therefore for the authors it is unclear what the numbers mean. However, we will check that during the typesetting of the paper this is corrected.

65. Table 1: see comment above: Reference required and show the three classes as mentioned in the text.

RESPONSE: Table 1 is explained in Section 3.2.4. The three classes were added to the table and references were added to the use of three categories in section 5.3 as follows:

However, indicator-based regional studies that classify vulnerability in 3 categories, have shown to provide useful information (Kappes et al., 2012; Liu and Li, 2015; Luino et al., 2012).

66. Table 2: Abbreviation PVE requires introduction. NOTE should not be written in capital letters. the term Estrada is unknown to the reviewer. Illegal origin should be rephrased, using the term as in the text consistently.

    RESPONSE: The introduction of abbreviation PVE was included in the section "Choice of indicators and principal component analysis for vulnerability assessment", therefore the note was deleted. Illegal origin was replaced by illegal settlements.

67. Figure 1: Lower left: km instead of Km, name the countries in the figure, show water or other geographic items (hillshade) which support the figure. Upper left: km instead of Km. Right figure: Cannot see the rivers (grey in grey). What is the overall study area? Outline required.

    RESPONSE: km was corrected. The names of the countries were included. Hillshade was included. Outlines in colour were added. The figure was changed to colour.

68. Figure 2: Transform into table. Figure is not readable at all (too small, no colours). What is EoV? Merge with parts of the text (see comments above).

Pressure instead of Preasure. What means block? Provide this table in coloured coding. Maybe split. Make sure the terms are consistent between table and text and that the table is complete.

RESPONSE: Figure 2 was transformed into table 1. The size of the table was increased and it was produced in colour. EoV was replaced by "effect". Some paragraphs were merged with the table. The word "Pressure" was corrected. "Block" was replaced by "Urban Block". The terminology of the paper was reviewed so it is consistent with the table.

69. Figure 3: Unclear, how to use this figure? Why not using numbers? Explanation required. A reference is essential, as this figure is from another publication, isn't it?

    RESPONSE: This figure is not from another publication. The reference Greiving (2006) was deleted o avoid confusion. In order to clarify how the matrix was used, the following paragraph was added:

    In order to combine the vulnerability and susceptibility to derive a level of risk, a classification matrix was used. This is shown in figure 2. The columns indicate the classification of the vulnerability indicator and the rows the classification of the susceptibility indicator. Only two priority outcomes are known, these are the high and low degrees assigned to the corners of the matrix corresponding to high susceptibility and high vulnerability and low susceptibility and low vulnerability (cells a and i), since they correspond to the extreme conditions in the analysis. The priority outcomes in cells from b to h were considered unknown and to potentially correspond to any category (low, medium or high priority). To define the category for these cells, the priority using all possible matrices (all possible combinations

of categories of cells b to c) was assessed for the watersheds for which flood records are available. Once, these watersheds were prioritised, a contingency table is constructed comparing the priority with the damage category (from table 3) from which the "proportion correct" is obtained. The classification matrix that results in the highest proportion correct (best fit) was used for the prioritisation of the whole study area.

70. Figure 4 and 6: The a/b/c are invisible. A legend is required in all figures. Provide in colour.

    RESPONSE: The size of the text "a/b/c" was increased. A legend was added to all figures and all are provided in colour.

71. Figure 7 and 8: References required, if this is not completely new. Otherwise, write own figure. Stick to scientific standards.

    RESPONSE: all figures were developed for the paper and are not based on figures created by other authors.

72. Figure 9: Colour essential. Legend required (instead of an explanation in the text). Some lines are invisible but required for the understanding. Numbering of watershed not logical.
    RESPONSE: The figure was produced in colour and a legend was added. The numbering of the watersheds in the Eastern Hills goes from 1 to 40 and in the Tunjuelo River Basin from 1000 to 1066. A note was added to the figure to clarify the numbering.