Author's response on *"Assessing residential buildings value in Spain for risk analyses. Application to the landslide hazard in the Autonomous Community of Valencia"* by I. Cantarino et al.

The authors are deeply appreciative of both Anonymous Referee instructive comments, which have led to the making of several corrections and have greatly aided us to improve the presentation of this paper. Our responses to individual comments are listed below in red.

Anonymous Referee #3

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1. Does the paper address relevant scientific and/or technical questions within the scope of NHESS?

   The (economic) assessment of natural hazards on the built environment is definitely an important topic for (natural) risk management. This question is not limited to landslide and potentially concerns any hazardous situation.

We fully agree with the importance of built environment and risk management, since we develop our main work in Civil Engineering.

2. Does the paper present new data and/or novel concepts, ideas, tools, methods or results?

   The paper is based on widely disseminated concepts, methods and tools. Several European FP7 research projects and PhD works deal with similar objectives.

We have made an effort for improving and detailing the concepts, methods and tools of our manuscript, as can be seen in the following pages.

Indeed, some European FP7 research projects deal with similar objectives. It is worth to highlight the SafeLand project, where a generic quantitative risk assessment, management tools and strategies for landslides are developed. Another research project is the MOVE, which creates knowledge, frameworks and methods for the assessment of vulnerability to natural hazards. These projects propose several guidelines for assessing risks and mapping, and analyse practice local cases. Some of these guidelines have been useful for the reviewing of this paper.

Our specific goal is to make a preliminary (not exhaustive) quantitative risk map GIS-based with our own data inside a large Spanish area. The scope and aim of FP7 is over the whole European territory.

We can add at p. 3617, line15, like the last paragraph: "Further, some European FP7 research projects deal with …. for the writing of this paper"

3. Are these up to international standards?

   Some of these works provide results that are more pertinent than the results presented in this paper. A more thorough literature review would improve the paper.

We have included new references, as can be seen at the end of this author's response.

4. Are the scientific methods and assumptions valid and outlined clearly?

   As with other similar works, “official public sources” (page 3637) (demographic, land use, ...) are cross-analysed. Strong limitations (that are common in academic works in this field) are mentioned in the paper: exclusion of non-residential building stock, restriction to building damages, exclusion of other direct damages, exclusion of intangible damages, reluctance to value human losses.

The “official public sources” are the National Statistic Institute (INE) for demographic and some characteristics building data and the National Geographic Institute (IGN) for the SIOSE land model. The scope, representation and reliability of both data are responsibility of the Spanish Government, and we trust on the consistence of these official data.

The definition of elements at risk heavily depends on the scope of the study, corresponds to the scale of investigation, and furthermore, is limited due to data constraints. Indeed, we have excluded some elements at risk, but we think that was unavoidable and has not affected to the final conclusions.

First, we have used the best detailed economic data for all types of buildings (residential or not) currently available in Spain for the whole territory. But, in the FFBVA report, the authors found that there is far less information available to carry out the assessment of “other constructions” than for the assessment of the housing stock. In other words, non-residential buildings are not disaggregated data with the detail of residential building.

Also, these “other constructions” represent only the 25% of the residential building. Nevertheless, the main problem is that the farming and ranching constructions -the elements more affected by the landslides due to their location in mountain areas-, are not dealt in the FFBVA study. Therefore, we have concluded that is better to exclude these data.

We have excluded the risk for life losses, which is not unusual, perhaps due to the intrinsic difficulty of its objective definition (Catani, 2005). The main Spanish landslides that took place during the last 150 years were described by Corominas (2005), where the number of casualty was 659 and about 700 injured. It is important to highlight that there were not casualties in the region that is objective of this paper during this period of time.

Nevertheless, this is not a minor aspect, but we will need to develop a specific methodology for assessing the human loss with absence of field information.

The impact on the other elements at risk should be considered (infrastructures, activities …), but the methodology is absolutely different and is difficult to be inserted in this paper. Of course, we believe it will be interesting and necessary to include all the losses in order to obtain a complete map of risk. At least, in this paper we have worked with the most prominent and highest impact economical items. We believe this could be a good tool for efficient planning and management in the distribution of resources in municipality policies.

We can add this explanatory text at the end of Section 2.2 (p. 3621, line 1), specifically: “We can justify that selection because there is far less information available to carry out the assessment of “other constructions” than for the assessment of the housing stock. In other words, non-residential buildings are not disaggregated data with the detail of residential building.

Also, these “other constructions” represent only the 25% of the residential building. Nevertheless, the main problem is that the farming and ranching constructions -the elements more affected by the landslides due to their location in mountain areas-, are not dealt in the FFBVA study. Therefore, we have concluded that is better to exclude these data.

Moreover, we have excluded the risk for life losses, which is not unusual, perhaps due to the intrinsic difficulty of its objective definition (Catani, 2005). The main Spanish landslides that took place during the last 150 years were described by Corominas (2005), where the number of casualty was 659 and about 700 injured. It is important to highlight that there were not casualties in the region that is objective of this paper during this period of time.

Nevertheless, this is not a minor aspect, but we will need to develop a specific methodology for assessing the human loss with absence of field information.

Finally, the impact on the other elements at risk should be considered (infrastructures, activities …), but the methodology is absolutely different and is difficult to be inserted in this paper.”

5. Are the results sufficient to support the interpretations and the conclusions?

   Consequences of these limitations are unfortunately not discussed in chapter 5 (discussion). This would represent an added value of the paper.

According with last point #3.4, described above, we will add at p. 3637, line 23: “There are some limitations about the elements at risk considered in this paper. We have exposed our reasons for that selection in Section 2.2. Anyway, we believe it will be interesting and necessary to include all the losses in order to obtain a complete map of risk. At least, in this paper we have worked with the most prominent and highest impact economical items. We believe this could be a good tool for efficient planning and management in the distribution of resources in municipality policies.”

Does the author reach substantial conclusions?

   Discussion on the above mentioned limitations would have probably influenced the conclusions. The reader of the paper would for instance be interested in knowing what the authors precisely know about the “land use, hazard and property market” in the Valencia area. This would help to better appreciate the declared pertinence of presented results.

There are papers in the references about the author’s works in these fields. Also, we are teaching in two University Departments dealing with subjects such as Geothecnics, Urban Planning, etc.

For example, Cantarino collaborates with the SIOSE land model -IGN team and the INE for demographic data, and shares works with the Department of Applied Economy at the University of Valencia. Moreover, Gielen is a professor and expert in GIS related to land-use planning. Palencia is an associate professor and has been hired by the regional authorities to collaborate, coordinate and write the review of the Territorial Action Plan flood risk in the Valencia region between 2009 and 2014; well as for determining the vulnerability of lifelines to the Special Plan of Seismic Risk in the Valencia Region in 2010. Palencia has been collaborating with the European FP7 Project “Smart Resilience Technology, Systems and Tools (SMARTeST)” (Project No. 244102) started on the 1st January 2010 and to be finished in 30th June 2013.

6. Is the description of the data used, the methods used, the experiments and calculations made, and the results obtained sufficiently complete and accurate to allow their reproduction by fellow scientists (traceability of results)?

   The core of the paper is the description of a method to evaluate and map floor surfaces of the main categories of residential buildings. This method is not original as such and can be reproduced as soon as statistical data are available.

The application of the dasymetric method for disaggregation of population is quite usual, but not much with economic data, by means of land use models. In Spain, the official source of statistical data (National Statistic Institute, INE) does not provide information to locate the type of buildings anywhere. We consider that the 2011 Spanish Census has been a lost opportunity for this purpose, since the Spanish Data Protection Law prevents this possibility.

For economic data, the Spanish Ministry of Finances has a land office registry (Cadastre) for dwellings and ground prices, but its data are not homogeneous for regional studies (These data have different reference date, and are not comparable). Unfortunately, we suspect that the complete data from official sources for regional studies in Spain will never be available.

7. Does the title clearly and unambiguously reflect the contents of the paper?

   The title of the paper partly reflects the core of the paper. Floor surfaces are adequately calculated but the (economic) value assessment is not clear in its purpose and method. Clarification would be needed concerning terminology: “value of residential buildings”, “reconstruction cost value”, “selling prices”, “financial value”, “market value”, “economic value”.

In the FBBVA report, the value assessment for buildings comes from a market study of the price of transactions prices of housing market for 451 areas in Spain. This is the first time that the value of the capital stock of housing has been estimated in Spain. With this information, and applying dasymetric technics, an assessment of the value of a residential dwelling can be made by a disaggregation of dwelling prices in a process based on the location of the different residential areas. As a result, we obtain the building value on a GIS model: this is the first step for the exposure calculations.

Indeed, there are some terms with synonymous meaning, as:
“Selling prices” == “market value”
“Value of residential buildings” == “economic value”
We will standardize these terms in the text

For the term “Reconstruction cost value”, we mean the total reposition value, as new rebuild on the same foundation: it is an insurance concept, normally refer to the building itself and not to any furniture, special features or other contents of the building prior to the damage, but is not the market value of the building. We will explain this in the manuscript (p. 3621, line2)

8. Does the abstract provide a concise, complete and unambiguous summary of the work done and the results obtained?

   The abstract reflects the structure of the paper and also reveals one of its strong weaknesses: “if hazard maps and risk assessment methods are available”. In the absence of valid risk assessment methods, results lose their interest.

The goal of this paper is not to elaborate a hazard map, rather the application of a type of hazard map for urban planning. We explain the interest on starting with a formed hazard map, in our paper, from the official map of risk of the COPUT (Regional Department of Public Works of the Valencia Government). That map is a useful and required tool, since is a necessary observance for urban and territorial planning at the Community of Valencia (COPUT, 2000), according with Article 63 of LOTTP law cited in our manuscript.

In fact, we have applied a risk assessment method on this map, with its own particular problems. The Article 63 points to the necessity for maintaining and updating this cartography in order to a rational territorial use. We hope that means an improvement over our current hazard maps.

We will modify this text for "After, with the application over a hazard map, the risk value can be easily obtained" (p. 3616, line 9)

9. Are the title and the abstract pertinent, and easy to understand to a wide and diversified audience?

   See above

10. Are mathematical formulae, symbols, abbreviations and units correctly defined and used?

    If the formulae, symbols or abbreviations are numerous, are there tables or appendixes listing them? Page 3620: Equation (1) is missing in the manuscript.(must be a misprint) Page 3626: NPj in Eq (2) is not defined

We have corrected these questions, NPj is NPi; but the Equation (1) is already in the text (p. 3619, line 13)

11. Is the size, quality and readability of each figure adequate to the type and quantity of data presented?

    Fonts of legends of figure 1 could be bigger.

We have corrected these legends edition problem

12. Does the author give proper credit to previous and/or related work, and does he/she indicate clearly his/her own contribution?

    The floor surface assessment is not original as such. The "value" assessment needs to be further clarified (for instance by a review of similar studies) The "hazard" (p. 3632) and "vulnerability" (p. 3633) sections cannot be accepted as such. Further considerations on vulnerability factors, damage mechanisms in the chosen landslide situation should for instance be proposed.

As described above, the value assessment for buildings comes from a market study of the price of transactions prices of housing market, explained in the FBBVA report. The most similar work to estimate building values for risk assessment was made by Kleist et al. (2006) in the project "Risk Map Germany", cited on the text and available on the NHESSD Journal. This is done on the basis of the Corine Land Cover dataset and a dasymetric mapping approach, and provides a uniform database on the reconstruction cost of potentially risk-exposed residential buildings in Germany at the community level.

We can improve the hazard section with the estimation of the temporal probability of occurrence of landslides in our area, over the basis of the official COPUT map. We choose to express this temporal occurrence as a frequency: number of events in a certain time interval. Also, as we are working with large area and small scales, is appropriate to express the ratio of the number of observed landslide events to the unit time (Corominas, 2014).

Unfortunately, in our country we have not a good detailed register of the distribution and characteristics of past landslides. The national landslide database has only 569 events on an inventory map 1:200000 that has not been updated. There are two regional landslide databases developed in Sierra Nevada (Andalusia, Granada) and Catalonia (Van Den Eeckhaut and Hervas, 2012).

As we need an estimation of primary level hazard, we must go to another source of data. Fell (2008) suggests as a primary method to assess the historic frequency of landslides from basic incident databases. Thus, in our area of study, we can know approximately the total number of historic landslides according the specific search on local newspaper records or similar sources. This question is addressed on the answer to reviewer in #4 3.a)

On the other hand, we quantify the vulnerability of an element at risk using a vulnerability index. This index expresses the degree of damage on a relative scale from 0 (no damage) to 1 (total damage). There are several methodologies used for the quantification of vulnerability according to the type of input data and the evaluation of the response parameters (Corominas, 2014). The data-driven methods are frequently used and they offer both simplicity and reliability, although they also introduce a degree of subjectivity.

Our cited lack of inventory data requires to obtain empirical index based in others authors (Leone, 1996), that increases the subjectivity but we can obtain a representative vulnerability. In a recent work on a regional scale for buildings and people as exposed elements, Zhigong Li (2010) define Vulnerability as a function with intensity and resistance to scenario-based landslide hazards.

We will remake the Section 4.3. with these last items, and after, with the explanation of the answer #4 3.a) and 3.b). See Annex 2.

13. Are the number and quality of the references appropriate?

    Further considerations will allow quoting more references.

We have incorporated new references (see at the end of discussion).

14. Are the references accessible by fellow scientists?

    Some old references but most are accessible (or can be identified) through internet

15. Is the overall presentation well structured, clear and easy to understand by a wide and general audience?

See above comments.

16. Is the length of the paper adequate, too long or too short?

17. Is there any part of the paper (title, abstract, main text, formulae, symbols, figures and their captions, tables, list of references, appendixes) that needs to be clarified, reduced, added, combined, or eliminated?

    See above and below comments.

18. Is the technical language precise and understandable by fellow scientists?

    The “hazard” (p. 3632) and “vulnerability” (p. 3633) sections need strong revision.

We have attempted to do this strong revision, as see below and on the response to referee #4, according with Annex 1 and 2. The full modifications we will be include in the paper.

19. Is the English language of good quality, fluent, simple and easy to read and understand by a wide and diversified audience?

    A final revision by a native English speaker would improve paper but it is not its main weakness.

We will improve, if necessary, the quality of the English language in this paper on the final revision, and checked by a proof reader of scientific English.

Anonymous Referee #4

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1. The state-of-the-art must be completed and updated. Some statements of the authors (i.e. page 3618: this type of map -risk map-has never fully developed and other similar comments in the introduction) suggest that they are not aware of the recent literature on the quantitative assessment of the landslide risk. I have included a few references below.

We would like to say this type of maps has never fully developed in our *study area* (Valencian Community). It is a well fact-known that this type of maps are presents and completely developed in some world regions (see case-studies cited in SafeLand FP7 program, 2012), even in Spain (Corominas, 2007).

We will change that text, p. 3618, line 1 “However, this type of map has never been fully developed in our case-study (Community of Valencia).”

2. Even though there is no a full consensus on the landslide risk terminology, some terms are used in the paper in a different way than other landslide experts, particularly the exposure and vulnerability. The authors should justify the definitions used while taking into account the following references: AGS, 2007; Fell et al. 2008; TC32; UNISDR, 2009. In my opinion, for instance, exposure and elements at risk (page 3619) are not exchangeable terms when dealing with landslides.

We can introduce some improvements in that terms according with the mentioned references in section 2.1 (p. 3619, line 15)

“HAZARD: A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. In technical settings, hazards are described quantitatively by the likely frequency of occurrence of different intensities for different areas, as determined from historical data or scientific analysis (UN-ISDR, 2009)

ELEMENTS AT RISK: The population, buildings and engineering works, economic activities, public services utilities, other infrastructures and environmental values in the area potentially affected by the landslide hazard (AGS, 2007; Fell, 2008)

EXPOSURE: People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses (UN-ISDR, 2009). Therefore, exposure indicates the extent to which the elements at risk are actually located in the path of a particular landslide (Corominas, 2014)

VULNERABILITY: The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide (AGS, 2007; Fell, 2008).”

In Section 4.1., p. 3631, line 16, we will add “Exposure is an attribute of people, property, systems or other elements present in areas that are potentially affected by landslides. It is calculated as the temporal and spatial probability that an element at risk is within the landslide path, and it also needs to be incorporated into the risk equation (Corominas, 2014)”.

In Section 4.2., p. 3632, line 2, we will add “The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the probability of their occurrence within a given period of time (Fell, 2008)”

3. a) The case study on risk assessment must be described in depth and completed. Particularly, it is necessary to explain how the different components of risk are obtained (landslide mechanisms, frequency, intensity, hazard, exposure, vulnerability). In this respect, the paper is ambiguous and plenty of contradictions.

The COPUT official map differentiates solely the rock fall (835 polygons) from the rest of landslides (flows and slides, 3584 polygons). In our region, with a Mediterranean climate, not very cold and dry, the rotational or planar slides are the more common types of instability.

Unfortunately, in Spain there are not a systematic and historic inventory of landslides and their consequences (see #3.12). Also, there are not wide official landslides records in our region, field works or remote sensing analysis. Consequently, the only way for knowing the landsliding temporal frequency is to consult local newspaper records, searching in their internet resources, or other ancillary sources. By this mean, we have found only about one ten of registered landslides in the last half century, on inhabited areas. These were: Arenós (1957), Alcoy (1958), Lucena del Cid

(1976), Monóvar (1987), Sueras (1987), Villahermosa (1987), Oliva (1987), Cortes de Pallás (1988), Altea (2007), El Toro (2008). Furthermore, we estimate that there were an equal number of unregistered events, at least, on the majority surface of uninhabited areas. Then, the average historical frequency of the Valencian Community wide is over 0.40 events/year (20/50) during this last 50-year period.

These landslides have a strongly heterogenic spatial-temporal distribution, function of the trigger mechanisms. In our area (and nearby), frequently these mechanisms are the high-intensity, short-lasting rainfall episodes on autumn when the sea still remains warm (about 100 mm/day). These episodes have a highly random distribution, so spatial both temporal (Corominas, 2006). By instance, the official Spanish rainfall record in 24h occurred in November 1987, when 817 mm fell a day in Oliva (Valencia).

For a landslide, the magnitude can be defined with several parameters including volume, velocity, depth, run-out, and area extent (Lee and Jones, 2004; Zhigong Li, 2010). It is considered that for a landslide event, we have one magnitude value but infinite intensity values. Intensity can be expressed in terms of either dynamic or geometric factor. We have no data in our catalogue for evaluating the dynamic factor. We can suppose that, with similar landslide mechanisms, the depth and velocity can be assumed virtually as a constant. Then, the intensity is function of the geometric factor, and can be set proportional to the area of the mapped landslide (Catani, 2005).

In the Table 9 (p. 3651), the intensity can be set in 3 classes, definite by the percentiles 3rd level:

Intensity 1 (Low) :	Landslides < 21.3 ha
Intensity 2 (Medium):	Landslides 21.3 – 56.1 ha
Intensity 3 (High):	Landslides > 56.1 ha

The hazard is the temporal probability. In our study, the best way for estimating this probability is by mean of the historical landslide frequency, due the input data. In this approach, we have not considered the bias introduced by the rainfall trigger mechanism, or another factors, and we have supposed an uniform distribution of the probability for the whole territory.

Then, the relationship between the number of annual historical events (0.40) between the total possible landslides (3584 polygons) provides us with an estimate of the average annual probability of failure for every one of the entire population of landslides. This probability is above 0.0001, and according with the classification of Lee and Jones (2004), the landsliding is highly unlikely, but not impossible within the design lifetime.

Finally, for our calculations and the purposes of the quantitative hazard assessment, we fit the "risk" class values of the COPUT map in terms of probability. Then, "low" was considered as 0.00025, "medium" 0.00050 and "high" 0.00075.

Exposure and vulnerability will be explained below

3. b) The input data are not clear. The Hazard Section (page 3632) suggests that risk is derived from a landslide susceptibility map rather than a hazard map. Several questions arise: what types of landslides are present in the area? are different landslide mechanisms considered in

the analysis? How is landslide intensity calculated? The vulnerability is a spatially distributed parameter (Van Westen et al 2005). How is this taken into account? Finally, a discussion on the appropriateness and reliability of the working scale (1:50,000) for this type of quantitative risk analysis is also required.

The main problem is that our official cartography from the risk COPUT map is not clear, but its method is based in to subdivide the terrain into zones with different likelihoods that landslides of a certain type may occur. This kind of maps primarily provides a proposed ranking of terrain units in terms of spatial probability of occurrence, and we must provide information on landslide period returns (Corominas, 2014). Thereby, these "risk" units have to be translated into annual probability, according with #4 3.a), for converting these classes in a true hazard map.

Then, we cannot consider different types of mechanism due to lack of data, and we assume an homogeneous region with similar landslide behaviour. We believe this simplified methodology is enough for our first approach.

As we say below, for evaluating the landslide intensity we must use the only one geometric parameter disposable, the area of landslide, and organized in three classes too (see #4 3.a)

Then, the vulnerability is calculated for each of the 3584 spatially distributed landslide polygons, according to V = f(I,R), see #4 3.a). This theoretical approach is the only way for assessing the vulnerability, because we have not historic data or loss estimation models in our region. In fact, this problem is usually one of the largest obstacles in land risk assessment (Van Westen, 2005)

Obviously, the working scale 1:50.000 in not appropriate for detailed studies, but our aim has been to obtain a primary tool for risk management at LAU2 level, and we believe sincerely that this scale is enough for our initial purposes. The main weakness of our source map is the lack of characterization of each cartography slide (probability, type, estimated depth …). We are convinced that for advancing in the quality of results is absolutely necessary to improve and to complete the source of data inputs and begin to make a landslide inventory database. Unfortunately, that work is not possible to deal with by our reduced work team, instead it should be guided and carried out by the Local Administration.

We can insert that last paragraph at Discussion Section, p. 3637, line 22

Annex 1 (Hazard Section)

We will modify the final of Section 4.2, p. 3632, line 11 to 25 with the following text:

"That COPUT official map differentiates solely the rock fall (835 polygons) from the rest of landslides (flows and slides, 3584 polygons). In our region, with a Mediterranean climate, not very cold and dry, the rotational or planar slides are the more common types of instability.

Now, we need to calculate the hazard with the estimation of the temporal probability of occurrence of landslides in our area, over the basis of the official COPUT map. We choose to express this temporal occurrence as a frequency: number of events in a certain time interval. Also, as we are working with large area and small scales, is appropriate to express the ratio of the number of observed landslide events to the unit time (Corominas, 2014).

Unfortunately, in Spain there are not a systematic and historic inventory of the distribution, characteristics and consequences of past landslides. The national landslide database has only 569 events on an inventory map 1:200000 that has not been updated. There are two regional landslide databases developed in Sierra Nevada (Andalusia, Granada) and Catalonia (Van Den Eeckhaut and Hervas, 2012). Accordingly, there are not wide official landslides records in our region, field works or remote sensing analysis

As we need an estimation of primary level hazard, we must go to another source of data. Fell (2008) suggests as a primary method to assess the historic frequency of landslides from basic incident databases. Thus, in our area of study, the only way for knowing the landsliding temporal frequency is to consult local newspaper records, searching in their internet resources, or other ancillary sources

By this mean, we have found only about one ten of registered landslides in the last half century, on inhabited areas. These were: Arenós (1957), Alcoy (1958), Lucena del Cid (1976), Monóvar (1987), Sueras (1987), Villahermosa (1987), Oliva (1987), Cortes de Pallás (1988), Altea (2007), El Toro (2008). Furthermore, we estimate that there were an equal number of unregistered events, at least, on the majority surface of uninhabited areas. Then, the average historical frequency of the Valencian Community wide is over 0.40 events/year (20/50) during this last 50-year period.

These landslides have a strongly heterogenic spatial-temporal distribution, function of the trigger mechanisms. In our area (and nearby), frequently these mechanisms are the high-intensity, short-lasting rainfall episodes on autumn when the sea still remains warm (about 100 mm/day). These episodes have a highly random distribution, so spatial both temporal (Corominas, 2006). By instance, the official Spanish rainfall record in 24h occurred in November 1987, when 817 mm fell a day in Oliva (Valencia).

As we have seen, hazard is the temporal probability. In our study, we can estimate this probability by mean of the historical landslide frequency. In this approach, we have not considered the bias introduced by the rainfall trigger mechanism, or another factors, and we have supposed a uniform distribution of the probability for the whole territory.

Then, the relationship between the number of annual historical events (0.40) between the total possible landslides (3584 polygons) provides us with an estimate of the average annual probability of failure for every one of the entire population of landslides. This probability is above 0.0001, and according with the classification of Lee and Jones (2004), the landsliding is highly unlikely, but not impossible within the design lifetime.

Finally, for our calculations and the purposes of the quantitative hazard assessment, we fit the “risk” class values of the COPUT map in terms of probability. Then, “low” was considered as 0.00025, “medium” 0.00050 and “high” 0.00075.

We cannot consider different types of mechanism due to lack of data, and we assume an homogeneous region with similar landslide behaviour. We believe this simplified methodology is enough for our first approach.”

Annex 2 (Vulnerability Section)

We will modify this Section as follows (p. 3634, line 4 to 11):

"There are several methodologies used for the quantification of vulnerability according to the type of input data and the evaluation of the response parameters (Corominas, 2014). The data-driven methods are frequently used and they offer both simplicity and reliability, although they also introduce a degree of subjectivity.

Our cited lack of inventory data requires to obtain empirical index based in others authors (Leone, 1996), that increases the subjectivity but we can obtain a representative vulnerability. In a recent work on a regional scale for buildings and people as exposed elements, Zhigong Li (2010) define Vulnerability as a function with intensity and resistance to scenario-based landslide hazards.

According with this author, Vulnerability (V) is a function of the hazard intensity (I) associated with exposed elements at risk and the resistance ability (R) of the elements to withstand a threat (R), then: V = f(I, R). Therefore, the vulnerability is calculated for each of the 3584 spatially distributed landslide polygons. This theoretical approach is the only way for assessing the vulnerability, because we have not historic data or loss estimation models in our region. In fact, this problem is usually one of the largest obstacles in land risk assessment (Van Westen, 2005)

For a landslide, the magnitude can be defined with several parameters including volume, velocity, depth, run-out, and area extent (Lee and Jones, 2004; Zhigong Li, 2010). It is considered that for a landslide event, we have one magnitude value but infinite intensity values. Intensity can be expressed in terms of either dynamic or geometric factor. We have no data in our catalogue for evaluating the dynamic factor. We can suppose that, with similar landslide mechanisms, the depth and velocity can be assumed virtually as a constant. Then, the intensity is function of the geometric factor, and can be set proportional to the area of the mapped landslide (Catani, 2005).

In the Table 9 (p. 3651), the intensity can be set in 3 classes, definite by the percentiles 3rd level:

Intensity 1 (Low) :	Landslides < 21.3 ha
Intensity 2 (Medium):	Landslides 21.3 – 56.1 ha
Intensity 3 (High):	Landslides > 56.1 ha"

New References

Catani, F., Casagli, N., Ermini, L., Righini, G., Menduni, G. (2005). "Landslide hazard and risk mapping at catchment scale in the Arno River basin". Landslides (2005) 2: 329–342. DOI: 10.1007/s10346-005-0021-0

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