

How map design shapes natural hazard risk understanding and perception: a case study from the Canton of Lucerne

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Dear colleague,

Thank you for your work. Please find below comments that I hope will help to improve the paper.

I would like to clarify that I did not use AI to evaluate your work (I used Deepl only).

First, I would like to clarify that the evaluation below concerns a 30-page paper consisting of two main sections: a 16-page main text (Abstract, Introduction, ..., Discussion, Limitations, Conclusion) and 14 pages of appendices (5 pages of tables, 4 pages of maps, and approximately 4 pages of references). The authors also mention “Supplementary Materials” (pages 4 and 9) - what are these?

This article, submitted to NHESS-EGUsphere, examines how participants perceive and understand natural hazard maps. Part of a master’s thesis, this publication is the result of a collaboration between researchers at ETH Zurich and natural hazard managers in the canton of Lucerne. This work was conducted as part of the revision of the “Federal Act on Watercourse Management,” published in August 2025 (see p. 13, § 350). This law applies to all Swiss cantons, which are required to develop general risk maps for the purpose of implementing protective measures (p. 2), land-use planning, and public communication (p. 2, § 35).

More specifically, the article aims (p. 3) to:

- analyze risk perception (awareness) and spatial understanding
- explore users’ map comprehension and visual preferences regarding the use of color and spatial details on a risk map
- How do individual factors (age, education, gender, homeowner/renter status, prior experiences) influence the perception and interpretation of risk maps?

The ultimate goal is to formulate recommendations for improving the visual presentation of natural hazard maps.

Three research questions are proposed:

***RQ 1*:** The impact of the visual variable “color” on the perception and understanding of natural hazard maps

***RQ 2*:** The impact of individual factors (age, gender, etc.) on the perception and understanding of natural hazard maps. Do these factors act as barriers or facilitate map reading?

***RQ 3*:** How do different cartographic approaches influence the perception and understanding of maps?

This evaluation will cover the following key points: the scientific state of the art, test maps and participants, the methods used (focus groups and an online survey), and the main findings.

The scientific state of the art:

Although the paper does not include a section or part devoted exclusively to the scientific literature related to the topic at hand, the introduction provides references on various aspects: risk management in Switzerland, risk communication, the role of cartography in communication, and the perception and understanding of maps in light of users' socio-economic and demographic factors.

In addition, bibliographic references are cited as the publication progresses. Aside from institutional and regulatory references (FOEN, FOS, Ref. in German, p. 13, § 350), some (how many?) are used or cited in a general manner and with little or no specificity. Examples:

**** p.2 § 50 :**

“Research has shown that people **often struggle** with **the interpretation of hazard maps** (Marti et al., 2019; San Martín et al., 2024).”

Yes, but this isn't specific to risk maps. It's also true for environmental, urban, and transportation maps, among others. Many people have trouble reading and using road maps just to find their way around!

« Une même carte, représentant un thème et un espace donnés, ne peut, sauf exception, être proposée de manière satisfaisante au regard de plusieurs publics distincts » (Cauvin et al., 2005).

A general understanding of cartography (from school education and personal experience) should help people better interpret natural hazard maps both in terms of form (symbols, scale, legend) and content (color-coded areas representing different hazards and risks).

Thus, the references below should be cited more precisely (“struggle”: which cartographic aspects did the participants find difficult to understand...?). Also, the context of the studies cited in the articles mentioned above is important.

** p.2 § 50 :

“Marti et al. (2019) demonstrated that a non-specialized audience can understand the main points of hazard maps, but interpreting these maps for specific purposes and answering advanced questions remains difficult.”

What does the term “demonstrated” mean? Research methods (based on questionnaires, focus groups, online surveys), while very interesting and important, remain empirical and statistical approaches. Statistics is an inexact branch of mathematics. Instead of “demonstrated,” wouldn’t it be better to say “these studies have shown...” or use an equivalent expression that would be more accurate?

** p.13 § 370 :

“These findings highlight the importance of a **rigorous** and **thoughtful** design process in the development of natural hazard risk maps (Dallo et al., 2024; Meyer et al., 2012; Schneider et al., 2025).”

The three references cited above were mentioned in connection with the rigor required for the design of risk maps, in particular. Many other references could be cited in this regard. The publication of research in a peer-reviewed journal (particularly regarding flood risk mapping) necessarily requires rigorous and thorough work. These studies (Dallo et al., 2024; Meyer et al., 2012; Schneider et al., 2025) can also—and especially—be cited in relation to the core of the topic under discussion. I did notice that Dallo et al., 2024 was cited in a much more interesting way elsewhere (“...research on earthquake risk communication in Switzerland, where older participants performed better in interpreting map-based information.” p. 14).

Another point related to the state of the art on which I would like to express some disagreement with the authors. It concerns paragraph 75 on page 3:

“Despite the recognised importance of effective visual risk communication, **empirical evidence remains limited. Only a few studies** (e.g., Dallo et al., 2020, 2024; Marti et al., 2019) have investigated this issue; however, no detailed study has yet been conducted for a synoptic risk map. Therefore, there is a clear need to assess how effectively prototype maps communicate natural hazard risks from a user perspective, particularly when designed to inform public awareness and promote preparedness.”

This publication focuses on the perception and understanding of risk maps through the evaluation of map prototypes (synoptic maps and zoom maps) with the participation of test persons. While this type of research remains challenging because it requires a significant investment of resources and time (time- and budget-consuming), there are indeed “many others” research studies closely related to your publication that are either not cited or cited only vaguely (see above).

*«...The interaction between the map user and the map itself has been a logical prime area of interest and research focus for over 70 years since the publication of Robinson's *The Look of Maps* (1952).» (David Fairbairn & Jess Hepburn, 2023).*

Here are a few examples of well-known studies on the effective participation of test persons in the evaluation of risk maps:

****1** Hegarty M., Smallman H.S., Stull A.T., Canham M. S., (2009). *Naïve cartography: how intuitions about display configuration can hurt performance*, *Cartographica*. 171-186 :**

“We assessed whether users prefer certain display enhancements (e.g., animation) over others (e.g., 3D) and whether they think that more enhanced displays are always better” and which ultimately also shows that « The results of this study are consistent with earlier studies showing that people prefer realistic displays even when their performance is impaired by these displays”. Hence the idea of “naïve cartography: desire for realism in our intuition results and a slowing with realism in the performance results”.

It seems that your article also shows that color doesn't have a particularly significant effect on the comprehension of the maps tested, which ties in with the previous citation! (please see also the following reference)

****2** Fabrikant S. I., Hespanha S. R., Hegarty M., (2010). *Cognitively inspired and perceptually salient graphic displays for efficient spatial inference making*, *Annals of the Association of American Geographers*, (2010), Vol. 100, 13-29. <https://doi.org/10.1080/00045600903362378>**

For example, the empirical study by Fabrikant et al. (2010) which tracked the eye movements (30 students with no prior experience in cartography) as they viewed weather maps, shows that the direction of the wind (a central element of the map) is a consequence of the atmospheric pressure system (the background). This study demonstrates how visual salience alone (high contrast, bright colors: map design) or combined with prior training of the subjects (user knowledge) influences map reading, thereby affecting the effectiveness of the map's message.

(see: Serrhini K., Moy Y., Noury G., Serrano J., Soltanpour H., "Vulnérabilité non-structurelle et résilience territoriale en situation de multi-risque. Perception et préférences cartographiques des aléas effondrement et inondation (val d'Orléans, Loiret, France)", *Revue Canadienne des Sciences Régionales (RCSR)*, vol. 46, N°2, **2023**, pp. 73-84. https://idjs.ca/images/rcsr/archives/V46N2_9-Serrhini.pdf).

****3** Fuchs S., Spachinger K., Dorner W., Rochman J. and Serrhini K., (2009). Evaluating cartographic design in flood risk mapping, *Environmental Hazards*, 8, 52–70, doi:10.3763/ehaz.2009.0007**

Meyer V., Kuhlicke C., Luther J., Fuchs S., Priest S., Dorner W., Serrhini K., Pardoe J., McCarthy S., Seidel J., Palka G., Unnerstall H., Viavattene C., and Scheuer S., (2012). Recommendations for the user-specific enhancement of flood maps, *Nat. Hazards Earth Syst. Sci.*, 12, 1701–1716, 2012. <https://nhess.copernicus.org/articles/12/1701/2012/>

As part of the European Floods Directive, Fuchs et al. (2009) and later Meyer et al. (2012) evaluated various European maps (flood hazard, damage, and risk) by analyzing the visual attractiveness of the test maps (eye-tracking data from 40 European volunteers), supplemented by a cognitive survey on message comprehension. Various parameters were tested: spatial scale, title, position and density of the legend, background (topographic map, infrared orthophoto), etc.

“Some of these authors’ recommendations should be used to improve the hazard maps included in the DICRIM (Ferrer et al., 2018)”.

The two previous references are cited in this article but are not necessarily closely related to the topic discussed, as noted above.

Finally, I’d like to show you the following references:

**** Panchaud N. H. & Lorenz H., (2018). Smart Cartographic Background Symbolization for Map Mashups in Geoportals: A Proof of Concept by Example of Land use Representation, *The Cartographic Journal*, 17 p.**

<https://doi.org/10.1080/00087041.2017.1414019>

**** Palka G.¹, Serrhini K., Thibault S., Néron E. (2016). « Conception cartographique individu-centrée : vers des plans d’évacuation plus efficaces », *Revue du Comité Français de cartographie : Cartes et géomatique, la sémiologie dans tous les sens*, N°229-230, Septembre-Décembre 2016, pp. 91-101.**

**** Gomez S., Domingès C., Aumond P., Lavandier C., Palka G., Serrhini K., "Cartographic representation of soundscape: proposals and assessment", In : *Citizen Empowered Mapping*, Michael Leitner et Jamal Jokar Arsanjani (Eds.), Springer, 2017, pp. 27-51.**

etc.

¹ **Palka G. (2015). Amélioration de la cartographie d’inondation par l’intégration des besoins et préférences des destinataires. Thèse en Aménagement de l’espace, Université François Rabelais de Tours. <https://theses.fr/2015TOUR1806>**

Test maps :

Regarding the test maps examined: they were produced as part of a collaborative effort between ETH and the Canton of Lucerne. There are four of these (synoptic) maps, which are shown in small size or format in Figure 1 on page 5. They also appear in the appendices, with one map per page (“A4”), on pages 22, 23, 24, and 25. These “A4” versions are much clearer than those on page 5. The resolution of the PDF document (article) makes the images on page 5 appear blurry. The A3 version provided to test persons must be visually much better than the “A4” version.

In terms of bibliographic references, there is no mention of the widely known works of cartographer Jacques BERTIN on graphic semiology (or semiotics). J. Bertin is the founder of an empirical approach related to the various visual variables (size, value, texture-structure, and COLOR...). Example: *Bertin, J. (1977). La graphique et le traitement graphique de l'information, Flammarion, Paris, 277 p.*

« Quand il s'agit de représenter avec la couleur un caractère ordonné, une carte “correcte” devrait utiliser un dégradé dans une seule couleur » :
Michèle BEGUIN, Denise PUMAIN, (ed. 1994 ... ed. 2017). - La représentation des données géographiques. Paris : Armand Colin (p. 39).

p. 23 :

“Figure C1 Synoptic risk map (Version 1; yellow–pink–purple colour scale) used in the online study to communicate the spatial distribution of natural hazard risk in the Canton of Lucerne, **integrating floods, surface runoff, avalanches, landslides, and rockfall into a single risk representation** (original format: A3). The arrow is connected to Table A7.” :

The legends for the synoptic maps indicate that each synoptic map depicts various natural hazards (floods, surface runoff, avalanches, landslides, and rockfalls) based on the frequency and intensity of these hazards. Taking into account the exposure of property and people, as well as indirect damages (“business” interruptions), these risks are to be expected!

First of all, do the hazards depicted on the four test maps represent historical events (in the Canton of Lucerne) or simulated scenarios (major events, such as a 10-year flood)?

Next, I am very curious to learn about the methodology used (by Lucerne and/or ETH) to achieve such a high level of aggregation of natural hazards (4 in total), vulnerabilities, and the resulting risks. The result is a RASTER map using a color gradient (4 versions: inspired by Craneri et al., 2020) representing 3 “levels” of risk (low, medium, and high): **discrete values within a continuous scale** (inspired by: Schneider et al., 2023; Severtson and Myers, 2013).

This simplified raster representation of a highly complex reality (multiple hazards—multiple risks!) is supplemented by toponymic elements (city name labels) and major transportation routes (roads and railways). The lakes of Lucerne are represented by hollow polygons (no blue fill to indicate water, etc.).

Admittedly, the prototype maps covering the entire Canton of Lucerne make it possible to identify the spatial distribution and concentration of different risk levels: the more densely populated an area is (in terms of people and urban assets), the higher the risk and vice versa.

However, how can one grasp the (potential) risk faced by a resident (at the level of their property, rental unit, or immediate surroundings) using raster maps where (approximately) 1.5 cm on the raster map corresponds to 9,000 meters on the ground? What is the resolution of each pixel in these maps?

Zooming in on a raster map would allow for a better view of the targeted area, but it does not change the pixel resolution of the raster. In other words, zooming does not effectively change the map's spatial scale for example, from 1:50000 to 1:25000. Zooming in does not reveal new spatial data (buildings, urban infrastructure, etc.) that would make the image more detailed and information-rich. Isn't that right?

Could you include an example of a zoom ("A4") in your article (at least in the appendices)?

More generally, is it possible to include a web link in the article (from any server, if the publisher allows it) that provides access to all the "supplementary materials"...

Mixed-methods approach : focus groups (FG) and online survey (OS)

The authors developed two approaches (a mixed-methods approach): focus groups (FS) and an online survey (OS).

** Focus groups (p. 6) discussions with experts (7 participants) and laypersons (6 participants) following a specific protocol (phases 1 through 5).

** Participation of 193 people from the Canton of Lucerne in an online survey (p. 8) to:

- answer questions about risk perception (sections 1 and 2) before viewing the test maps;
- evaluate proposed risk maps (one randomly selected synoptic map (C1, C2, C3, or C4) plus two zoomed-in process maps per participant) according to a predetermined protocol (blocks 3 and 4);
- re-evaluate perceptions and preferences after reviewing the test maps (block 5);
- evaluate and compare participants' preferences regarding the cartographic background (block 7).

Did the 7 experts from the canton of Lucerne participate in the development of the test maps before becoming part of the FG sample? In other words, were they already familiar with such maps prior to their evaluation (potentially eliminating the surprise effect)?

Furthermore, were the 7 experts part of the sample (193) of OS participants?

The opportunity to participate in the entire process (FG + OS) would make it possible to measure and evaluate changes (evolution) in the perception and understanding of natural hazards and the associated maps.

« laypersons would accept living in higher risk zones if the location was sufficiently central...” (p. 7 § 185) :

Have these test persons themselves or their loved ones experienced a flood or landslide?

Do the maps truly allow us to VISUALIZE the impact of the natural hazards under study on daily life: how many flooded buildings, the impact on daily commuting, and what about the water level is inside buildings...?

A large-scale raster representation, no matter how complex, does not really allow us to visually grasp such impacts: « Process comprehension scores were consistently higher than synoptic comprehension scores” (p. 11 § 305).

« Experts further regarded the maps as more suited to institutional applications than ... to private decisions” (p. 7 § 185).

“Laypeople found mountain regions difficult to identify” (p. 7 § 200) :

Given the significant topography (mountain) in this canton, why wasn't a prototype 3D map included?

More generally, the visual variables targeted by the study (research questions and objectives) could have been specified more clearly.

Similarly, if appropriate, could an example of maps—before and after improvements based on the dual-method approach (focus groups and online survey)—be included?

Please, see the collective publication below related to RiskMap (European research project, Era-Net Crue programme) :

Meyer, V., Kuhlicke, C., Luther, J., Fuchs, S., Priest, S., Dorner, W., Serrhini, K., Pardoe, J., McCarthy, S., Seidel, J., Palka, G., Unnerstall, H., Viavattene, C., and Scheuer, S. (2012). Recommendations for the user-specific enhancement of flood maps, Nat. Hazards Earth Syst. Sci., 12, 1701–1716, <https://doi.org/10.5194/nhess-12-1701-2012>

See, for example, the map (page **1709**) of “Fig. 2. Example of a map for emergency management (case study: Saxony): Map contents include flood depth and the affected population, as well as important emergency management information (coordination center, assembly points, evacuation routes) and critical infrastructure...”.

I have no idea about how the findings of this research will be incorporated into official planning and crisis management documents regarding emergency response, humanitarian rescue and mass evacuation.

In addition, recent studies have organized recommendations for improved flood risk mapping in terms of **effects** (see: RiskCatch, RiskMap, Gaëtan Palka; Serrhini, 2000 and 2026), including:

(1) The text effect: to decipher the map’s message, participants systematically examine textual elements (title, legend, place names)—undoubtedly a cultural expression

(2) The color effect: the impact of color on the map’s aesthetic dimension is undeniable. While the use of color helps bridge the gap between cartography and the real world as experienced and/or perceived by users, color—just like the use of 3D—can detract from the main message (see Hegarty et al., 2009)

(3) The contrast effect: This can be used to highlight certain spatial features representing heightened vulnerability or an evacuation route. This effect should be used sparingly due to the strong visual pull of high contrast, which can divert attention from the essential message.

Finally, perception is said to be both **anthropic** (dependent on the user) and **iconographic** (related to the perceived image). What do you think?

Regarding the format, here are just a few points:

** Table 1, p. 9: Focus directly on the 193 selected participants (instead of N=197). The participants who were not selected are mentioned in the text.

** It is not clear how the scoring system(s) for the various questions works (on which scale(s): out of 5, 10, or 20; e.g., M = 1.56 out of 5, p. 10, § 280)?

This scoring scale appears to vary (see examples of M values in Table A1, p. 17) .

We also do not fully understand the indices, particularly the aggregated ones. An example could be included each time as the text progresses (either in the main text or in the appendices).

But can the scores from different questions and answers be aggregated? Aren't the answers to subsequent questions more or less influenced by those to previous questions?

** For comparison purposes, can we perform an analysis (as below):

ANOVA_1: "Map Design 1 + the 2 zoomed-in process maps"

ANOVA_2: "Map Design 2 + the 2 zoomed-in process maps"

ANOVA_3: "Map Design 3 + the 2 zoomed-in process maps"?

Finally, a global ANOVA: Map Designs 1, 2, and 3 + the 2 zoomed-in process maps?

** Finally, the approach (mixed-methods) is far from being standardized, and initially, it is up to the author to implement it repeatedly at different sites (Canton de Lucerne, others Canton and maybe in others UE sites) to demonstrate the approach's reproducibility (within certain limits).

In conclusion, I propose that this article be published after revisions and improvements have been made.

I remain at your complete disposal.

Dr. K. Serrhini