Effects of Uncertainty Visualization on Decision Making and User Confidence: An Empirical Study

by **Metrine Bwisa**

Uncertainty in information affects how users utilize the given information [1]. This thesis investigated the effects of uncertainty on user decision making and subsequent confidence, based on flood risk maps.

The study was conducted on Kenyan geography experts and novices user groups. Experience with uncertainty visualization and encounter with floods were used to further categorize the users.

Analysis was done, first to investigate if the users interpreted uncertainty shown by color value and texture overlay appropriately. Secondly, the study investigated if the inclusion of uncertainty resulted into changes in the decisions made prior to provision of uncertainty. The variation in user confidence when uncertainty was provided was also analysed.

Background

Uncertainty visualization has not yet been standardized as a mapping technique despite more than 20 years of research. In an attempt to address research gaps in this domain, Smith Mason et al. recommended that more focus should be put on individual differences and users' prior knowledge to understand how these affect user interaction with uncertainty visualizations [2].

Kunz et al. also researched on visualization of uncertainty on hazard maps such as flood risk maps [3]. They interviewed Swiss natural hazards experts, who were reluctant to communicate uncertainties contained in hazard maps [3]. The aforementioned research gaps and Swiss hazard experts' reluctance motivated the focus of this research.

Visualization Methods

Based on recommendations from 18 reviewed literature, the following visualization methods were investigated:

1. Coincident approach
2. Static technique
3. Intrinsic colour value
4. Extrinsic texture overlay

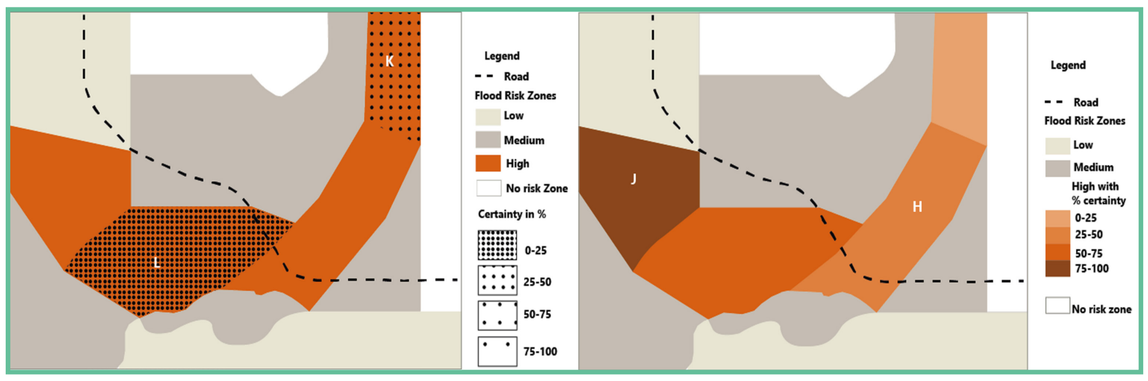

Fig. 1: The right map shows certainty information on high flood risk zones represented by texture overlay and the left map by color value. Users were asked to chose the riskiest zone in each map

User Study

The questionnaire was answered by 53 respondents aged between 21 and 46 years. They were required to:

- Read and interpret flood risk maps with and without uncertainty information
- Make decisions to stay or leave a location based on flood risk and uncertainty
- Indicate the confidence in their decisions

Fig.1 illustrates uncertainty represented by texture overlay and color value. Users were asked to indicate the riskiest zones in each of the maps shown separately.

Findings

- Both the experts and novices user groups interpreted uncertainty by color value and texture overlay appropriately
- Inclusion of uncertainty caused changes in the decions as illustrated in fig. 2 and 3
- Although novices interpreted color value uncertainty better than texture overlay, the difference in interpretation of the two techniques was statistically insignificant
- There was no statistical difference between decisions made by respondents with and those without floods encounter

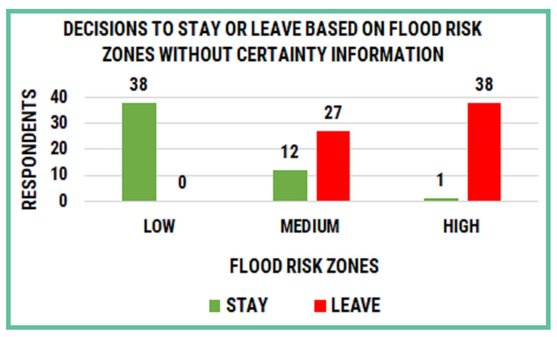

Fig. 2: Users' decisions to stay or leave the flood risk zones without provision of uncertainty

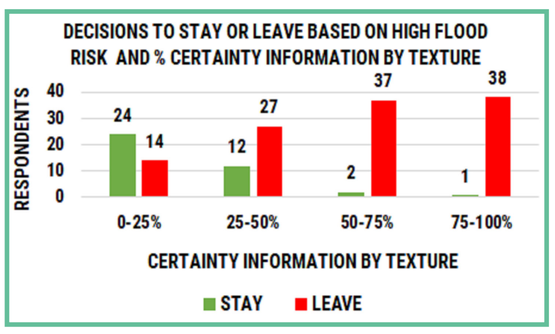

Fig. 3: Users' decisions to stay or leave the high flood risk zone with uncertainty information

- When 75-100% certainty was provided in the low risk zone, users who changed their decisions recorded statistically significant higher confidence levels than those who maintained their decisions as illustrated in Fig 4

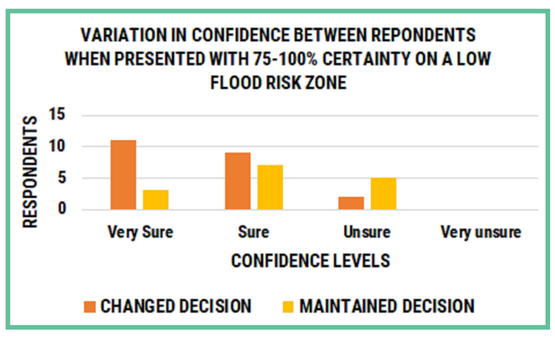

Fig. 4: Higher confidence by users who changed decisions compared to those that maintained decisions when given 75-100% certainty in the low flood risk zone

- Inexperience in uncertainty visualization did not have a negative effect on the interpretation of color value and texture overlay uncertainty

Conclusion

Uncertainty visualization presents users with important information for consideration in decision making. This enables them to make informed decisions and has potential to increase user' confidence in their decisions.

Thesis Conducted at

Research Division Cartography
Department of Geodesy and Geoinformation
Technische Universität Wien

TECHNISCHE UNIVERSITÄT WIEN

Supervisors

Univ.Ass. Mag.rer.nat. BA. Silvia Klettner, TU Wien

Year

2019

Keywords

uncertainty visualization, color value, texture overlay, decision making with uncertainty, user confidence

References

[1] A. MacEachren, A. Robinson, S. Gardner and S. Hopper, "Visualizing Geospatial Information Uncertainty: What We Know and What We Need to Know", Cartography and Geographic Information Science, vol. 32, no. 3, pp. 139-160, 2005. Available: 10.1559/1523040054738936.

[2] J. Smith Mason, D. Retchless and A. Klippel, "Domains of uncertainty visualization research: a visual summary approach", Cartography and Geographic Information Science, vol. 44, no. 4, pp. 296-309, 2016. Available: 10.1080/15230406.2016.1154804.

[3] M. Kunz, A. Grêt-Regamey and L. Hurni, "Visualization of uncertainty in natural hazards assessments using an interactive cartographic information system", Natural Hazards, vol. 59, no. 3, pp. 1735-1751, 2011. Available: 10.1007/s11069-011-9864-y.

This master thesis was created within the Cartography M.Sc. programme – proudly co-funded by the Erasmus+ Programme of the European Union.

Technische Universität München · TECHNISCHE UNIVERSITÄT WIEN · TECHNISCHE UNIVERSITÄT DRESDEN · ITC UNIVERSITY OF TWENTE. · Erasmus+ · cartographymaster.eu