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Review of the Habilitation Thesis of Jan Brus

The habilitation thesis entitled "*Uncertainty and Quality of Spatial Data in Environmental Analyses: From Visualization to Decision-Making*" submitted by Jan Brus presents a comprehensive and methodologically rich contribution to the field of geoinformatics, with a particular emphasis on environmental applications and decision-support processes. The work reflects a long-term and coherent research trajectory that evolves from the technical understanding of spatial data quality toward a broader, user-centered conceptualization of uncertainty and its communication.

The thesis is structured logically around four research questions that guide the reader from theoretical conceptualization through methodological treatment and visualization to practical applications. This structure ensures a clear narrative and demonstrates the candidate's ability to integrate multiple strands of research into a unified framework. The work is based on a synthesis of eleven peer-reviewed publications, which are not presented as isolated outputs but are effectively interwoven into a coherent argument. This approach is appropriate for a habilitation thesis and reflects a high level of scientific maturity.

From a theoretical perspective, the thesis addresses an important and well-recognized gap in geoinformatics and cartography, namely the fragmentation between technical approaches to data quality, methods of uncertainty visualization, and their practical use in decision-making. The author proposes a user-centered framework that shifts attention from purely data-driven processes to the needs, cognitive abilities, and decision contexts of end users. This shift is well justified and aligns with broader developments in related disciplines, including human-centered design and information visualization. The distinction between data quality as a measurable property and uncertainty as a broader concept encompassing perception, communication, and interpretation is clearly articulated and represents a valuable conceptual contribution.

However, while the proposed framework is well argued and pedagogically effective, its theoretical originality is somewhat limited. The concept of user-centered design is not new, and similar principles have been discussed in cartography and visualization research for some time. The main contribution of the thesis therefore lies less in introducing a fundamentally new theory and more in integrating existing concepts into a coherent and practically applicable framework tailored to geospatial data and environmental analyses. This integrative contribution is

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nonetheless significant, particularly given the complexity and interdisciplinary nature of the problem.

The methodological part of the thesis is one of its strongest aspects. The author demonstrates the ability to work with a wide range of approaches, including expert-based data interpretation, participatory data collection through citizen science, spatial modeling, and experimental validation using eye-tracking technology. The diversity of methods reflects the complexity of uncertainty in environmental data and shows the candidate's versatility as a researcher. Particularly noteworthy is the effort to operationalize otherwise abstract concepts, such as the quantification of expert confidence or the transformation of subjective citizen perceptions into analytically usable data. These contributions have clear practical relevance and represent meaningful advances in applied geoinformatics.

The empirical validation of uncertainty visualization methods using eye-tracking experiments deserves special attention. This part of the work addresses a critical gap in the literature, where many visualization techniques have been proposed without sufficient testing on real users. The finding that subjective preferences do not necessarily correspond to actual performance is both important and convincingly demonstrated. At the same time, it should be noted that the experimental design, including the number of participants and the controlled conditions, may limit the generalizability of the results. Future work could expand on this by testing visualization approaches in more realistic decision-making environments.

The application-oriented chapters clearly demonstrate the practical impact of the research. Case studies focusing on mosquito outbreak mapping, beekeeping management, invasive species modeling, and decision-support tools for local governance illustrate how the proposed framework can be implemented in real-world contexts. These examples show that the author is not only capable of theoretical and methodological work but also of translating research into tools and processes with tangible societal benefits. The integration of citizen science data is particularly compelling, as it addresses both the opportunities and challenges associated with participatory approaches and highlights the importance of systematic validation and communication of uncertainty.

Despite these strengths, some limitations should be mentioned. The case studies, while diverse and well presented, are often context-specific, and the extent to which the proposed framework can be generalized across domains is not always fully demonstrated. In addition, the evaluation of practical impact remains largely qualitative. More systematic assessment of how the proposed approaches improve decision-making outcomes would further strengthen the contribution. The discussion section could also benefit from a more critical reflection on the limitations of the proposed framework, including situations in which it may not be applicable or where trade-offs between simplicity and accuracy become problematic.

In terms of presentation, the thesis is generally well written, clearly structured, and accessible to readers from related disciplines. The logical progression from theory to application is particularly effective. Nevertheless, some sections are descriptive and could be more concise, and certain arguments are repeated across chapters. A more focused synthesis in the discussion could enhance the overall clarity and impact of the work.

In conclusion, the habilitation thesis by Jan Brus represents a high-quality and substantial contribution to geoinformatics, particularly in the domain of uncertainty and data quality in environmental analyses. Its main strength lies in the integration of theoretical, methodological, and applied perspectives into a coherent and practically relevant framework. While the theoretical novelty is moderate and some aspects could be further developed, the overall scientific level,

originality of application, and societal relevance of the work fully meet the expectations for a habilitation thesis.

I therefore recommend that the thesis be accepted and that the habilitation procedure be continued.

Yours sincerely,

Vienna, 4.4.2026, Univ. Prof. Dr. Georg Gartner