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Insight-Based Evaluation of a Map-based Dashboard

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Abstract—Map-based dashboards are used for data exploration every day. The present study used an insight-based methodology for evaluating a map-based dashboard that presents research findings of water management and ecosystem services in the Amazon. In addition to analyzing the insights gained from using the dashboard, the evaluation method was compared to standardized questionnaires and task-based evaluations. The result suggests that the dashboard enabled the participants to gain domain-relevant, complex insights regarding the topic presented. Furthermore, the insight-based analysis highlighted unexpected insights and hypotheses regarding causes and potential adaptation strategies for remediation. Although time- and resource-consuming, the insight-based methodology was shown to have the potential of thoroughly analyzing how end users can utilize map-based dashboards for data exploration and decision making. Finally, the insight-based methodology is argued to evaluate tools in scenarios more similar to real-life usage, compared to task-based evaluation methods.

Keywords—Visual analytics, dashboard, insight-based evaluation, geographic visualization.

I. Introduction

PLANNING for the future is a complex and extraordinary challenge. Geographical and spatial planning requires accounting for various factors such as water management, provision of food, risk reduction from natural habitat, and socio-economic structures [1], [2]. Because most decision makers are not scientists nor experts, effective communication techniques such as visual representations are crucial to bridge the gap between science and decision making [3], [4]. Map-based dashboards have been developed [5], [6] to support decision makers in complex environmental reasoning leading to better, science-based, spatial planning. By combining interactive maps with indicators, such as key performance indicators (KPIs), dashboards make it possible to visualize research findings in user-friendly formats [1] (as an example, see Johns Hopkins' COVID-19 dashboard [7]).

Developing and maintaining such dashboards requires considerable resources [4]. Therefore, it is meaningful to evaluate how end users interact and gain insights from dashboards as decision-support tools. This knowledge not only validates the means for creating the dashboards but can also guide new ways of improving them. However, methodologies for evaluating these types of high-level questions are not often used for applied cases in the industry and are reported sparsely in papers [1], [8].

The present study aims to use the insight-based methodology proposed by North [9] to evaluate a dashboard built by the Natural Capital Project at Stanford University. The dashboard studied, the *Pro Agua viewer*, is a map-based dashboard built for presenting water-related ecosystem services in the Amazon. Through a series of interactive maps, charts, and easy-to-read text, the dashboard aims to inform decision makers of where ecosystem services will be vulnerable in the future under different scenarios.

This study contributes to the visualization research community by:

1) evaluating a dashboard for watershed management,
2) assessing the use of the insight-based methodology for analyzing the usability of a map-based dashboard, and
3) making suggestions about how knowledge from analyzing the insights can aid further development of similar visual analytic tools.

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II. Background

Dashboards are visual displays containing the most important results of a specific data set [10], [11]. Objectives of dashboards are to create awareness and facilitate actionable understanding to support end users in making well-informed decisions [12], [3], [13]. Dashboards can communicate an overview of the data, allow for zoom and filter, and then provide details on demand, which resembles the Visual Information Seeking Mantra [14]. A useful dashboard can thereby support decision-makers in understanding complex situations and thus trigger a discussion about strategy and preventative actions [15], [3], [16], [4].

Understanding the usability of map-based dashboards includes methods from several fields: Cartography provides methods for evaluating the maps layers, Human computer interaction (HCI) allows for the evaluation of the interface, and finally, methods from the Visualization field favor the evaluation of how the visual representation can provide insight [17]. This type of research, bridging the gap between visualization research and applications, is important for making sure that visualization prototypes and techniques reach a state that can be used by end users [18].

Well designed interactive maps hold potential for improving spatial decision making [19], [20], [21]. These maps allow decision-makers to generate new serendipitous insights by enabling them to consider both spatial and environmental, economic, and social aspects [22]. The maps help to transfer knowledge from the map maker to the map user [23]. However, more research is needed to understand what interactions are needed for which decisions, and also, what interactions as necessary for what types of decision-makers (spatial planners, economics, politicians, etc) [21].

Furthermore, despite the increasing use of evaluations of tool functionality and usability [24], [8], [25], extensive user-evaluation of visual representations built for

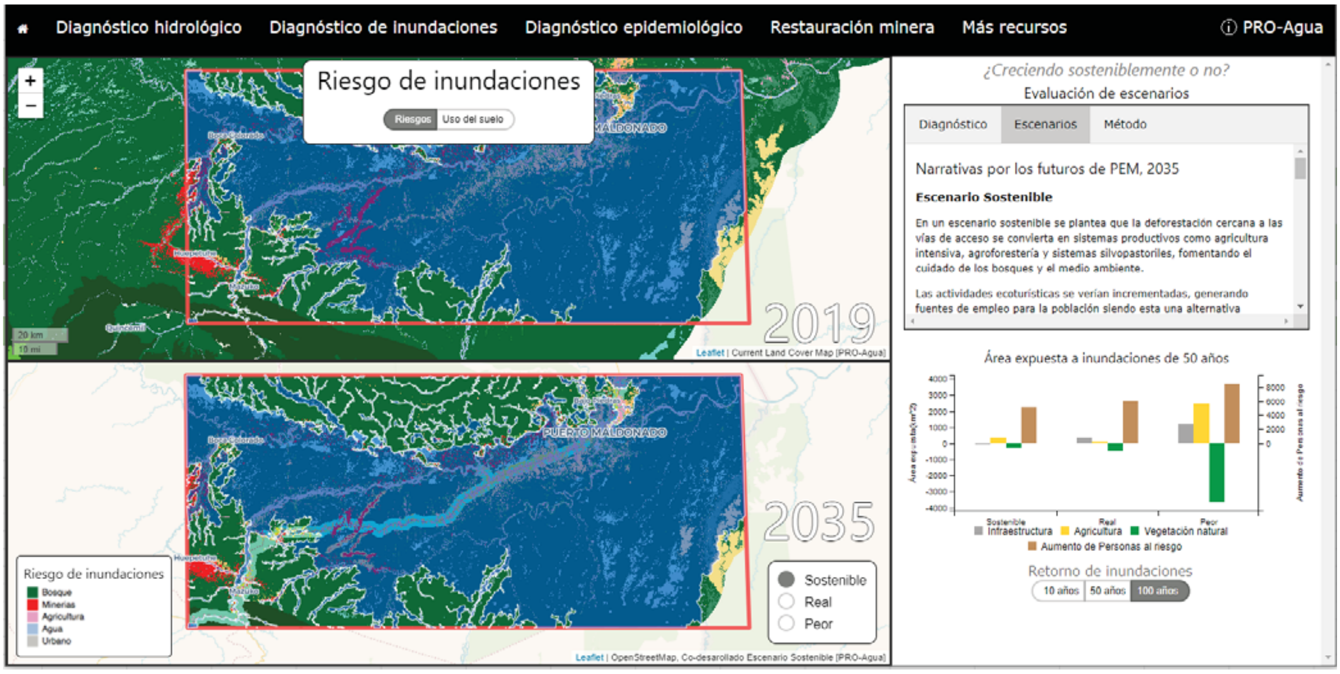

Fig. 1 The Pro Agua viewer: The displayed view presents the predicted flooding in Puerto Maldonado in 2035 with flood risk levels, and information about diagnostics, scenarios, and methods, as well as a bar graph presenting areas (such as infrastructure and agriculture) exposed to flooding

domain-specific work are less common [13]. If evaluations are conducted, these are often stated without extensive explanation of how the results were achieved and not reported formal enough to use for cross-comparison with other visual representations [1], [8]. Moreover, the fact that decision-support tools are used for various purposes, and by various types of end users, makes these harder to evaluate in a quantified manner [26]. A qualitative approach has, therefore, proven to be essential when evaluating visual analytic tools. Qualitative methods investigate real problems of real end users which are of importance when building tools for real applications [8], [26]. However, reviewers are often rejecting qualitative approaches based on the preconceptions that such studies were non-rigorous and not valid [27], [8].

For evaluating higher-level issues such as exploration, insights, and decision making, the scenario of evaluating *Visual Data Analysis and Reasoning* (VDAR) [26] has been proposed. The aim of VDAR is to assess a visualization tool's ability to support visual analysis and reasoning about data. Such an evaluation can generate quantifiable metrics regarding insight as well as subjective statements about quality and data analysis experience. Only 2.9% of the evaluations were mapped to VDAR according to a survey of evaluation techniques in the field of visualization [8]. Another evaluation approach is the *value-driven evaluation* (ICE-T), that aims to explore the value of a visualization by the *time* that is needed to understand the represented data, the *insights* gained, the comprehension of the *essece* of the data, and finally the *confidence* and knowledge about the data [28]. Conducting more evaluations, using VDAR or ICE-T, would be beneficial, providing both further understanding about visualization as a support for data exploration, and within the context of evaluating the usefulness of map-based dashboards [8], [1].

One of the proposed methodologies within VDAR is the insight-based methodology [9], which is used in the present study for evaluating the Pro Agua viewer. The insight-based methodology observes and records what insights participants *gain on their own* instead of instructing participants on what insights they *should get*. In this context, insights can be described as observations or discoveries found by the participant in the data [29]. The recorded insights are then coded and analyzed based on a set of characteristics like Domain Value and Correctness (see Section IV). The methodology has previously been used for applications of clinical data [30], health and well being [31], and bioinformatics [32], [29]. Common for these studies is the focus on open-ended protocol, insight analysis, and the domain-knowledge-relevance of the chosen participants [9].

III. Case Study: A Brief Introduction of the Pro Agua Viewer

The *Pro Agua project* (Proyecto Resiliencia y Ordenamiento Territorial del Agua, translated as Water Resilience and Land Management project) is a collaborative effort by local projects in South America and the Natural Capital Project at Stanford University. The project aims to demonstrate the benefits of ecosystem services and comprehensive watershed management for the health and well-being of the growing population in the Amazon. It aspires to increase understanding of improved usage of the area and its resources, which would support sustainable development for a better future.

The *Pro Agua viewer* [33] (see Fig. 1) was developed to share and communicate the project's complex data and results in a user-friendly format. Moreover, the dashboard aimed to support decision makers, both on a local and national level, with various levels of expertise. The dashboard can be used during workshops and discussions, not daily. Therefore, it needs to express the data understandably without any introduction.

The dashboard displays the project's findings via a series of interactive maps, graphs, and photographs. Results are presented in two separate views, one presenting data related to dengue fever and one presenting data related to flooding. The layout of the two views is similar. Two maps are displayed. The first includes the current land use and the second three possible future scenarios for land use. On the second map, the end user can add layers that display how that future land use will impact the risk of dengue fever respectively flooding. In the flood view, the second map also presents the consequences of different flood periods.

In addition to the maps, several bar charts summarize the overall risk for dengue fever or flooding in each area for each future land usage scenario. The charts also present how many people will be impacted under which scenarios. Finally, the dashboard includes some complimentary text to help explain the data presented.

IV. Method

The present study was conducted using an application of the insight-based methodology in addition to an adjusted version of the SUS questionnaire [34]. The recorded insights were defined as observations or discoveries found by the participants [29] and analyzed based on 5 characteristics.

- **Observation/Fact:** The finding or observation in the data made by the participant.
- **Domain Value:** The value or significance of the insight gained by the participant. The value was defined by the complexity and depth of the finding. The scale was coded on a five-point Likert scale from 1, a trivial observation, to 5, a deep understanding of underlying relations that integrates knowledge about the area or topic.
- **Hypotheses:** Some insights leading the participant to identify a new relevant hypothesis. This suggests in-depth data understanding as the new insight is combined with previous knowledge.
- **Directed vs. Unexpected:** Directed insights were expected by the developers of the dashboard, while unexpected were not considered in the design of the tool but emerged from using it.
- **Correctness:** Level of correctness of the insight found by the participants. Correctness was also coded on a five-point Likert scale from 1, fuzzy or wrong insight, to 5, precise and correct insight.

The characteristics used were based on the original work by North [9] and previous similar case studies [31], [32], [29]. They allowed further analysis and distinguishing between different types of insight. The insights were coded independently by two coders. For Domain Value and Correctness, the means of the two coders' results were used. For Hypotheses and Directed/Unexpected, inconsistencies between the coders were discussed until consensus was reached.

A. Participants

In total, the evaluation included interviewing 16 participants, of which 12 of them met the inclusion criteria of no previous usage of the viewer. Ten of these worked in direct domain-relevant fields in the Amazon area: natural infrastructure (four), Engineer environmental/geography (three), Ph.D. in Geography or Biology (three), and two were master students in geology (B.Sc Geology). The participants came from local organizations acquainted with the Pro Agua project. After each interview, participants could suggest other potential participants available for an interview.

All interviews were in English, in the interest of keeping all data in the same language. This language barrier limited the number of possible participants and was the main factor as to why the study did not include more interviews.

B. Test Protocol

The user tests were conducted as short (30 minutes) recorded interviews. Each participant used their own computer and shared their screen. At the beginning of each interview, the participants were asked to answer some background questions about their knowledge about the Pro Agua project and knowledge about data analysis and visual representations. The interviews were divided into two parts for which the first part consisted of an exploratory session and the second part of a usability questionnaire.

The exploratory part of the interview started with a short tutorial of the viewer. For 10 minutes, participants were then requested to use the Pro Agua viewer to investigate the topics of flooding and dengue fever related to land use. A think-aloud protocol was used, and the participant was encouraged to talk about both hunches or validated reasoning. The participant could ask questions about the functionalities of the tool but not about the data itself. After the exploratory session, the participant was asked to answer adjusted statements from the SUS questionnaire [34] about their experience of the interface (see Table II). Finally, each interview ended with an open discussion in which the participant could provide feedback on the viewer and the research.

V. Results

Through the insight-based method, the dashboard was evaluated by 12 potential end users. During the twelve 10 minutes sessions, the participants gained 141 insights (see Table I). These insights had a mean Domain Value of 2.8 and a mean Correctness of 3.9. 30% (n = 43) of the insights were Hypotheses, and 28% (n = 40) were Unexpected (insights the creators did not originally design the dashboard for). On average, the participants reported that they had gained 60% of all potential knowledge (ranging from 30-100%) after their session.

The results suggested that all participants gained domain-relevant insights. The mean number of insights was 6.8 (ranging from 3-12 see Fig. 2), only considering insights with Domain Values higher than 2, which removed all low-level insights like "*This is the flood in the area.*" 25% of the insights had a Domain Value of 4 or higher, which could suggest that the participants were able to gain complex insights from the data. Furthermore, only 4% of the insights had a Correctness less than 3, which indicated that participants were not misled nor wrongly interpreted the data.

The insights were grouped based on the participants' previous knowledge about data analysis and the Pro Agua project (see Table I). Participants with Pro Agua and data analysis knowledge (Subgroup A1) and participants with only data analysis knowledge (Subgroup A2) generated more hypotheses than those participants without any previous knowledge (Subgroup A3). Insights found in Subgroup A1 had the highest mean Domain Value, while insights from Subgroup A3 were slightly more correct. Participants in Subgroup A3 could, in general, find more insights than participants in other groups.

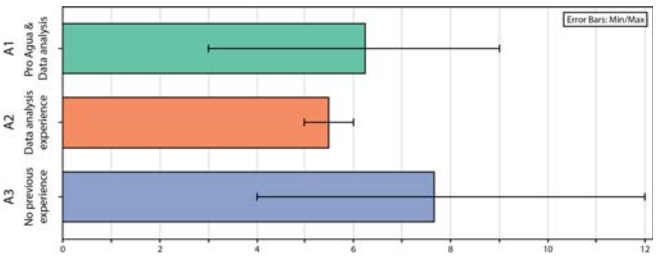

Fig. 2 Gained insights (Domain Value > 2) for each Subgroup

TABLE I
SUMMARY OF THE INSIGHTS ANALYSIS

	All	A1	A2	A3
Participants, *n*	12	4	2	6
Mean insights/person	11.8 (4.7)	9.8 (3.8)	10 (2.8)	13.7 (5.5)
Hypotheses, %	30.5	46.2	45.0	19.5
Unexp. insights, %	28.4	41.0	25.0	23.1
Mean Domain Value	2.8 (1.1)	3.1 (3.1)	2.7 (1.6)	2.7 (1.0)
Mean Correctness	3.9 (0.6)	3.8 (0.6)	3.8 (0.8)	3.9 (0.6)

A1 - Data analysis and Pro Agua knowledge, A2 - Data analysis knowledge, A3 - No Pro Agua knowledge nor data analysis knowledge.

The results suggest that Hypotheses were more likely to have higher Domain Values compared to simple facts (see Fig. 3). The Correctness did not differ much between Hypotheses and simple facts, although the results suggest that Hypotheses were slightly less correct. The same goes for Unexpected vs. Directed insights. Unexpected insights generally had higher Domain Values whereas Directed insights had higher Correctness.

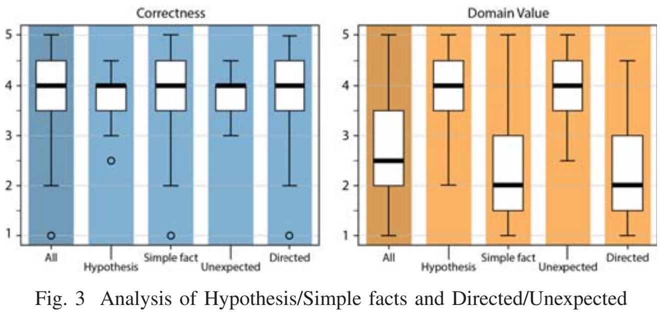

Fig. 3 Analysis of Hypothesis/Simple facts and Directed/Unexpected insights for Correctness and Domain Value

Overall, the participants rated all usability statements fairly high (see Table II). The lowest score was given to the statement "*The dashboard is providing all information I need*" because participants thought they needed more data to make a decision. There is no correlation between participants' individual ratings and how many insights they had actually gained.

TABLE II
RATINGS FROM THE PRO AGUA VIEWER USABILITY QUESTIONNAIRE USING A FIVE-POINT LIKERT SCALE

	Mean	Min	Max
Easy to learn	4.0	3.0	5.0
Need of introduction	2.0	1.0	5.0
Easy to use	4.5	4.0	5.0
Provides all information	3.0	1.0	4.0
Provides all functionalities	4.0	3.0	5.0
Easy to find what I am looking for	4.0	3.0	5.0
Provides confidence	5.0	3.0	5.0
Pleasant interface	5.0	4.0	5.0
Useful as decision support	4.5	4.0	5.0
Provides domain-relevant insights	5.0	3.0	5.0

VI. DISCUSSION AND FUTURE WORK

The results suggest a difference in the Domain Values of insights gained based on participants' knowledge levels. Participants with previous experience of Pro Agua, or data analysis, could gain more complex insights. In summary, all participants regardless of subgroup showed examples of insights with high Domain values, high Correctness, Hypothesizes, and Unexpected insights. It is, therefore, suggested that the Pro Agua viewer could be useful for various types of user groups which is essential for its aims.

The insight-based methodology provided considerable knowledge, both by presenting what insights participants could gain from the viewer, but also in terms of indicating which graphs and map-layers were most in need of improvement. For example, one chart presented slightly unconventional results only as bars but not in the chart caption. Because there was no text commenting on the result, the participants often wrongly assumed they were misreading the chart. This finding was prominent in the insight analysis by low Correctness and Domain Values on the recorded insights regarding that chart. Moreover, comments and participants insights also initiated a discussion amongst the researchers that created the data. After reviewing the evaluation, the researchers saw an inconsistency in the data which was found to be inherited from an error in the data algorithm. Performing the analysis hence did not only improve the design of the dashboard but also increased the quality of the data.

A. Content Analysis of the Insights

Most insights (124/141) came from the maps, which suggest that they were most noticed and enabled most insights. From the insights regarding the maps, 40/124 came from comparing the two maps (current situation and future scenario). This highlights that displaying several views might aid the end user in connecting how different data relates to each other.

> ”What I care about is how many people are exposed to higher risk and I can see that in the worst scenario it is 80 000 people at greater risk.”

From analyzing the content of the insights it was discovered that all twelve participants had at least one insight regarding people and how future scenarios would impact them. These insights were often extended with words describing how important these questions were to them.

> ”I guess for the sustainable scenario you would also have to invest a lot of money so it would be interesting to see how much.”

The different scenarios were often an entry point to the participant starting to discuss specific strategies, or who they would involve in upcoming decisions. However, many of the participants asked for more details and guidance regarding the cost and where exactly it would be most beneficial for them to place their efforts.

B. Method Limitations

The Pro Agua viewer is aiming at providing a fast overview of the results from the Pro Agua project and is not meant to be used daily. Therefore, the present study investigated first-time users and what they could interpret from just a short 10 minutes session. In previous work using the insight-based methodology, sessions were longer because those studies investigated tools with other use cases. Furthermore, another aspect of insights could be measuring the time it takes for the participant to reach it [28]. Because of the COVID-19 pandemic, the sessions were recorded through video meetings. Measuring the time would not have been valid because there were several interruptions during the sessions due to lost internet connections. Nonetheless, analyzing time constraints could be interesting for future work.

The insight-based methodology needs considerable time for interviews and analysis [30]. The method further requires domain experts for rating the insights, and motivated participants that keep finding insights without being given specific tasks [29]. These resources are expensive and might not be available for all cases. Nonetheless, compared to the present study’s questionnaire (and arguably also other standard questionnaires), the insight-based methodology provided a preeminent understanding of (1) how well the participants actually understood the dashboard, (2) how the dashboard could promote the discovery of new hypotheses, and (3) if gained insights corresponded to the scientist’s intentions. These are all benefits that evaluation techniques within VDAR presents [8], [1]. However, future research is still needed to standardize the insight-based methodology for further evaluation of dashboards. The method would then facilitate comparing two visual representations with the same or different data sets. This comparison enables a deeper examination of design choices considering maps and metrics as well as interaction. What design choices are most helpful for which data sets could then be concluded [21].

VII. Conclusion

The present study aimed to use the insight-based methodology to investigate the usefulness of a map-based dashboard, resolving in the following conclusions: (1) the insight-based methodology has the potential for a thorough analysis of end users’ understanding of a visual representation and use for data exploration. Compared to task-based methods and standardized questionnaires, the insight-based methodology evaluates the tools in scenarios more similar to real-life usage. Therefore, it also better demonstrates the usability in real use cases. (2) The analysis of insights guided improving the viewer to avoid misinterpretation of the data. Results guided changes both regarding the design, such as adding more descriptive text but also initiated a new revision of the data. The results further suggest that participants appreciated having two maps, one with the current situation and one for future scenarios. Two maps allowed for a quick overview and comparison, and the final dashboard kept this design. Finally, evaluating the dashboard illustrated the span of different hypotheses and conclusions extractable from the data. It suggests that the dashboard is useful and, in extension, that similar map-based dashboards could have the potential of serving as valuable decision support tools.

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