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The Russia-Ukraine war and climate change: analysis of one year of data-visualisations

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The Russian invasion of Ukraine in February 2022 escalated a conflict that began in 2014, resulting in massive casualties and the largest refugee crisis since World War II. The war has also disrupted global food and energy trade, significantly impacting the environment, including damage to critical infrastructure, increased greenhouse gas emissions, and dire consequences on biodiversity and environmental health – connecting the war to climate change. Effective communication is crucial in helping the public understand and feel engaged with these complex topics. This study aims to understand how the research communities and broader media have linked the war to climate change, how this connection has been visualised, and what can be learned from the approaches. We surveyed 1192 papers or articles from ten research and media venues. We collected 202 data visualisations, 59 from articles connecting the dimensions of the war and climate change, concluding that energy is the most explored topic, with finance/commerce also significantly represented, and that data visualisation strategies used are limited in narrative and chart types. The study leverages this knowledge to propose implications for the design of future climate change interactions.

Keywords: data visualisation; climate change; war; communication design

1 Introduction

Progressive strides are gradually being taken in the realm of climate change, including the United States' climate policy that promotes a shift towards renewable energy sources and financially supports climate-related innovations, as well as the establishment of a fund dedicated to assisting developing nations in managing the impacts of climate change (Sengupta, 2022). However, most countries must meet climate pledges (Dalton & Hua, 2022). Focusing on action and solutions is more critical than ever, and practical and engaging communication is essential. Visual representations of information and metaphors, especially novel and unexpected ones, are crucial in helping the public perceive highly complex topics. Examples are the Doomsday Clock (Mecklin, 2023) – a visual metaphor for how close we are to human-made destruction; the Warming Stripes graphics (Hawkins, 2019) – data

visualizations representing the change in temperature over time; or the Time magazine cover created by artist Olafur Eliasson that uses an optical illusion that would communicate the current climate urgency (Pine, 2022). Compelling visualisations are fundamental, particularly with topics that generate vast amounts of data that must be analyzed and shared.

Discussions about effectively engaging people with data are not new and have become even more pressing in times of crisis. On 24 February 2022, Russia invaded and occupied parts of Ukraine, escalating a conflict from 2014 (Ellyatt, 2022) and causing the largest refugee crisis since World War II (UNHCR, 2022). Above all, the Ukrainian people have suffered through massive casualties, forced migration, and the widespread destruction of infrastructure. In response, the International Criminal Court (ICC) has recently opened an investigation into possible war crimes, crimes against humanity, the abduction of children, and genocide (ICC, 2022). The war also has a hugely detrimental impact on the environment and climate change mitigation efforts (Brown et al., 2023) – damage caused by military operations, including destroying critical infrastructure and releasing hazardous materials into the air, soil, and water. The conflict has also led to increased greenhouse gas emissions due to military efforts, the use of fossil fuels and the disruption of renewable energy projects. President Zelenskyy's address at 2022's COP27 (Harvey et al., 2022) focused on these effects, giving as examples the hectares of forest destroyed, the threat of radiation disaster from nuclear plants, the energy crisis that was leading countries to continue or revert to coal, and the food crisis caused by disruptions to grain exports (Baker, 2022b). The war also has dire consequences on biodiversity (IFAW, 2023) and environmental health (Vykhor & Beckmann, 2022). Outside Ukraine, the effects of the war have been far-reaching, especially for the global energy landscape (IEA, 2023). The war spotlighted countries' dependence on Russian oil and gas, the need for energetic self-sufficiency, and the push toward renewables. The latest Intergovernmental Panel on Climate Change (IPCC) report underlines this issue by stating the urgency of phasing out fossil fuels and finally starting emissions decrease before 2025 if we hope to keep global heating below 1.5ºC (Shukla et al., 2022).

In the past year, this new crisis has populated our news. In particular, the topics of war and climate change were correlated, presenting the added challenge of conveying this data in ways people find relatable while leading away from hopelessness. Considering the importance of the Ukraine war in the current social and economic landscape and its effect on climate change, we saw the first anniversary of the conflict as an opportunity to understand how visualisations addressed these topics. We set out to answer the following research questions: (RQ1) After one year of the war, how have the research communities and the broader media linked the war to climate change; (RQ2) How was this connection visualized; (RQ3) What can we learn from the approaches so far and what can we propose for future work. To address these questions, we surveyed 1192 papers or articles from ten research and media venues that addressed the war and climate change during the first year of the conflict. We collected 202 data visualisations, 59 of which united both dimensions. Our analysis concluded that Energy is the topic most explored, with Finance/Commerce also significantly represented. This result denotes the energy crisis's effect on broader society and the importance of energy dependency and transition in the climate change debate. We also found that the data visualisation strategies used are minimal in the narrative and chart types used.

With this study and the suggestions for future work, we contribute to the design community by sharing our findings about how research and media communicate and visualize the connection between the

war and climate change and how we can leverage this knowledge to improve future climate change engagement and communication.

2 Related work

In this section, we examine the connections between war, climate change, and visual communication strategies that can help increase engagement and understanding of these critical issues.

2.1 War in Ukraine and its effects on climate change

Climate change and its consequences occupy the top six spots of the ten most significant societal risks (WEF, 2023). The ongoing war between Russia and Ukraine poses an existential threat to Ukraine (Rawtani et al., 2022) and has far-reaching impacts on the climate and climate-security risks. Some examples are water and soil contamination, air pollution, and increased emissions due to military interventions (McNutt & Hildebrand, 2022). The war has also triggered unprecedented increases in global energy and food prices, impoverished millions worldwide, and led to the highest number of refugees in Europe since World War II (Brown, 2023). As a UN report puts it, the war compromises "our aspirations for a better world by 2030" (UN, 2022).

The link between wars and climate change has already been the focus of research (Berhe, 2022; Roche et al., 2020; Sakaguchi et al., 2017). President Zelenskyy's address at 2022's COP27 (Harvey et al., 2022) focused on this connection through the war's impact on the *environment* – for example, the 2 million hectares of forest destroyed – on *energy* – the threat of radiation disaster from nuclear plants and the energy crisis that was compelling countries to continue or revert to coal – and *food* – through the disruption of grain supplies (Ukraine and Russia together export 30% of the world's wheat (Baker, 2022a)) that is worsening the food crises already exacerbated by droughts (Jägermeyr et al., 2021).

While the war's impact inside Ukraine has been devastating in terms of carbon pollution, with vast amounts of greenhouse gases released by the destruction of infrastructure and the use of diesel generators, the impact outside Ukraine has been paradoxically more positive (Nugent, 2023): the disruption of gas imports from Russia accelerated the global phase-out of fossil fuels as countries turned to renewables for energy security; Europe's non-electricity natural gas consumption has fallen by 17% since the start of the war, leading to a reduction of 117 metric tons of carbon emissions. However, the ultimate impact of the war on the world's long-term ability to tackle climate change remains to be determined (Brown, 2023).

2.2 Climate change communication strategies

Climate change communication is a complex issue due to the scale of the problem, which requires widespread citizen participation and systemic change (IPCC, 2018; Wuebbles et al., 2017). It involves conveying a multitude of data, urgency, and the underlying science, also considering how this information is imparted and the impact these communication choices might have. Ongoing debates and experiments with differently framed climate change messages have produced mixed results. Studies suggest that fear messages cause stronger reactions than hope (Hornsey & Fielding, 2016), not presenting a significant difference to risk perception (Ettinger et al., 2021), or that simple reframing of climate policies most likely won't increase public support (Bernauer & McGrath, 2016).

Other studies point to fear being an ineffective tool for motivating personal engagement with climate change topics (O'Neill & Nicholson-Cole, 2009), that positive framing reinforces support (Dasandi et

al., 2022), or that there is a preference for messages framed without negative emotions (Bloodhart et al., 2019). Along the same line, recent guidelines for climate change communication highlight the importance of framing interactions positively to avoid a "feeling of hopelessness" (Corner et al., 2015). Narrow narratives focusing exclusively on "doom and gloom" can leave the public feeling powerless (Arnold, 2018) and can even lead to psychological distress (T. J. Doherty & Clayton, 2011). Especially with the COVID-19 pandemic and the war in Ukraine, crisis fatigue is even more of a reality (Bloodhart et al., 2019; Flinders, 2020). Recent social movements are fighting against “climate doomism” and focusing on action and hope (Adcock, 2022; Buckley, 2022; Hassol & Mann, 2022).

Climate change should be presented as solvable (Popli, 2022), shifting the focus from sacrifice to what becomes possible (Mayer & Smith, 2019; Tonkinwise, 2011). Solution-oriented messages can help to increase engagement (K. L. Doherty & Webler, 2016; Feinberg & Willer, 2011; Hart & Feldman, 2016), and "hope appeals" can be a powerful tool for persuasive communication (Chadwick, 2015). The data needs to be presented accurately and in a relatable way, using stories, graphs, and statistics to connect with the audience (Chapman et al., 2016; Corner et al., 2018). Personal stories can be a persuasive communication strategy to engage diverse and even sceptical audiences (Gustafson et al., 2020), but a broader selection of narratives is needed (O’Neill et al., 2015).

A recent survey of climate change-related projects suggests that communicators should select topics based on impact and audience, adapt the narrative to what matters to them, and explore alternative and more inclusive perspectives (Ferreira et al., 2022). Climate change communicators can leverage the connection between the environmental impact of the Ukraine war, its constant media coverage, and the direct impact on people's lives in their messaging. However, they must consider the discussed suggestions and guidelines to avoid further defeatism.

2.3 Visualising war and climate change

The use of visual communication is common in the depiction and explanation of war, usually portraying battles, military strategy, and the effect on people through the use of photography or video (Engberg-Pedersen & Maurer, 2017; Ojala et al., 2017). However, certain information can only be conveyed or understood through data visualisations. Examples of this are the work of Florence Nightingale during the Crimean War, informing decision-making in the British government (Bradshaw, 2020), or Charles Joseph Minard, best known for his flow maps, particularly the one about Napoleon's Russian campaign (Rendgen, 2018).

There is no consensus on the optimal approach to visualizing complex data for non-expert audiences (Meloncon & Warner, 2017). Over the past thirty years, leading authors on data visualisation have emphasized design efficiency and clear communication, which can be categorized as a "neutrality" principle (Zhao & Sun, 2022). Tufte suggested a distraction-free approach focused on presenting the actual data and avoiding "chartjunk" (Tufte, 2013), while others stressed the importance of accuracy and clarity for effective communication (Few, 2012) , cautioned against the persuasive misuse of data visualisations (Cairo, 2016), or advocated for following applied human perception (Ware, 2021).

Alternative approaches emphasize a more ambiguous and humanistic representation of data, considering that data is not value-neutral or observer-independent (Drucker, 2011). McCandless proposed a storytelling approach that combines information, story, goal, and visual form (McCandless, 2014). Lupi advocates a move away from impersonality and questions established principles of data

visualisation, such as the obligation of keeping visualisations simple (Lupi, 2017). The purpose is to create more emotional, personal, and engaging connections with data (Richards, 2022; Zhao & Sun, 2022). These principles align with the communication guidelines for climate engagement discussed in the previous section (United Nations Department of Global Communications, 2022). However, the designer needs to avoid biased or misleading representations of data. Ciuccarelli and Lupi argue that data is biased and influenced by the people who create it and their social context. A balance of accuracy and interpretation is needed. Furthermore, how we present data, language use, and visual choices influence who is included or left out of the data discourses (Ciuccarelli, 2022).

Data visualisations about conflicts have been subject to these different approaches. Topics explored range from territory changes and troop movements to economic shifts, casualties, and military spending, to name a few (Roser et al., 2022). The ongoing war in Ukraine is no exception (Ritchie et al., 2022). In recent years, technological advances have enriched and augmented data visualisations, making them more interactive (e.g. (Marques et al., 2021)), including visualizing war (Arfected, 2022; Nguyen et al., 2019). Web-based interactive infographics or dashboards have become commonplace. The interactive documentary The Fallen of World War II (Halloran, 2015) is a prime example of the use of data storytelling, narrative and interaction to visualise the staggering data related to the human casualties of war. More subjective data visualisations about war have also been developed, such as Poppy Field (D'Efilippo & Pigelet, 2001), both a printed visualisation and an installation also representing casualties of conflicts through the position, colour and size of poppies. These are examples of how storytelling with data can help the reader understand complex facts (Rodríguez et al., 2015) through a more experiential form.

Climate change has likewise been visualized in many forms, from global temperature maps to charts showing rising sea levels. One prominent example is NASA Global Climate Change (Shaftel et al., 2023), which uses a variety of interactive visualisations to show changes in temperature, sea level, and other critical indicators over time. Another example is the Climate Central platform (Climate Central, 2008), which features an interactive sea level rise map that allows users to explore the potential impact of rising seas on coastal communities worldwide. Other visualisations include the "hockey stick" graph (Mann et al., 1999), which shows the sharp increase in global temperatures in recent decades, the famous Keeling Curve (Scripps Institution of Oceanography, 2013), which shows the steady rise in atmospheric carbon dioxide levels since the 1950s, or Climate Stripes (Hawkins, 2019), showing temperature changes over time in different locations. These visualisations have been fundamental in representing the global and oftentimes invisible effects of climate change. They also help make the complex climate change issue more accessible and understandable to the general public. However, these measures can still feel abstract and impersonal due to their magnitude and long-term effects.

Considering the Ukraine war's importance in current affairs, its effect on climate change and the direct connection to people's day-to-day, linking these two dimensions presents an opportunity for climate change engagement. The first anniversary of the conflict came as an opportune time to investigate how these topics were connected and visualized. This study aims to ultimately learn from the approaches employed and propose strategies that can lead to more engaging human climate change interactions.

3 Methodology

This research looks at how communication strategies have been used to visualise the Ukrainian War. To rigorously gather and analyze a corpus of representative work, we followed the Grounded Theory Literature Review method (GTLR) (Wolfswinkel et al., 2013), based on Grounded theory (Glaser & Strauss, 2009). This method has developed a rigorous approach to analyzing materials to derive new themes, issues, or opportunities. These themes, or key concepts, surface from data gathering and analysis instead of being inferred beforehand. To mitigate problems that could arise from using this method – related to *credibility*, *transferability*, *dependability*, and *confirmability* (Bitsch, 2005) – we aimed to be transparent about the choices made during the data gathering and analysis, which we describe in this paper. Furthermore, the analysis and results were iteratively created and discussed throughout the process by the authors.

Our analysis followed the five iterative stages of GTLR: 1) *Define*: the most suitable data set was identified; 2) *Search*: where the data is gathered; 3) *Select*: refines the samples to be analyzed; 4) *Analyze*: qualitative research methods are used to extract value from the collected set; 5) *Present*: oversees the writing of a coherent overview paper (the article in hand). In the following sections, we describe how we followed these stages to collect and analyze a corpus of 1192 articles from ten research and media venues, from which we gathered 202 data visualisations.

3.1 Work scope and data collection

In this section, we describe the first three stages of the analysis. In the first phase, we start by defining the scope of the study. Our investigation centred on the Russia-Ukraine war and its relationship to its environmental impact and climate change. Our search spans one year since the date of the invasion of Ukraine by Russian military forces (Ellyatt, 2022) – from 24 Feb. 2022 to 2023. We selected ten venues to consider our research interests in design, HCI, and information communication and visualisation by the broader media. By focusing on research venues and broader media, we intend to accomplish a general overview of the main approaches being explored. Within the research community, we used the ACM SIGs: sigchi, sigcomm, sigdoc, or siggraph; the DRS Digital Library; and IEEE Vis. We did not consider the IASDR proceedings since the last conference occurred in 2021. We eliminated full proceedings and focused on individual articles. To represent the broader media, we focused on seven of the most-read newspapers and magazines worldwide that had an English presence online: The New York Times (NYT), The Washington Post (WP), The New Yorker (NY), The Guardian (TG), The Wall Street Journal (WSJ), Forbes, and Time Magazine.

We then proceeded to the Search phase. We focused on the keywords "war" OR "Ukraine" AND "climate change" within the timeframe. We looked into each article for venues with under 500 results to gather if they included a data visualization. If so, we added them to our list. For media with over 500 results – WP (2390), TG (6350), and Forbes (1700) –, we added additional keywords to narrow down the search: “visualisation”, “visualisation”, “infographic”, or “visual”. We chose these keywords after analyzing articles that did contain a visualisation, and how they referred to it (when they did).

Some adaptations were necessary depending on the venue’s search options. For The New York Times, we searched for the keywords “war” or “Ukraine” within their Climate section. For The Guardian, Forbes, and Time, we used Google search within their specific domains to search for the keywords within our timeframe. For IEEE Vis 2022, we analysed articles through their titles, abstracts, and keywords to gather them.

The selection criteria applied resulted in a list of 1192 papers or articles. In the Select phase, we focused on the articles that contained one or more data visualization or infographic. From the initial list, 137 met these criteria (Fig. 1).

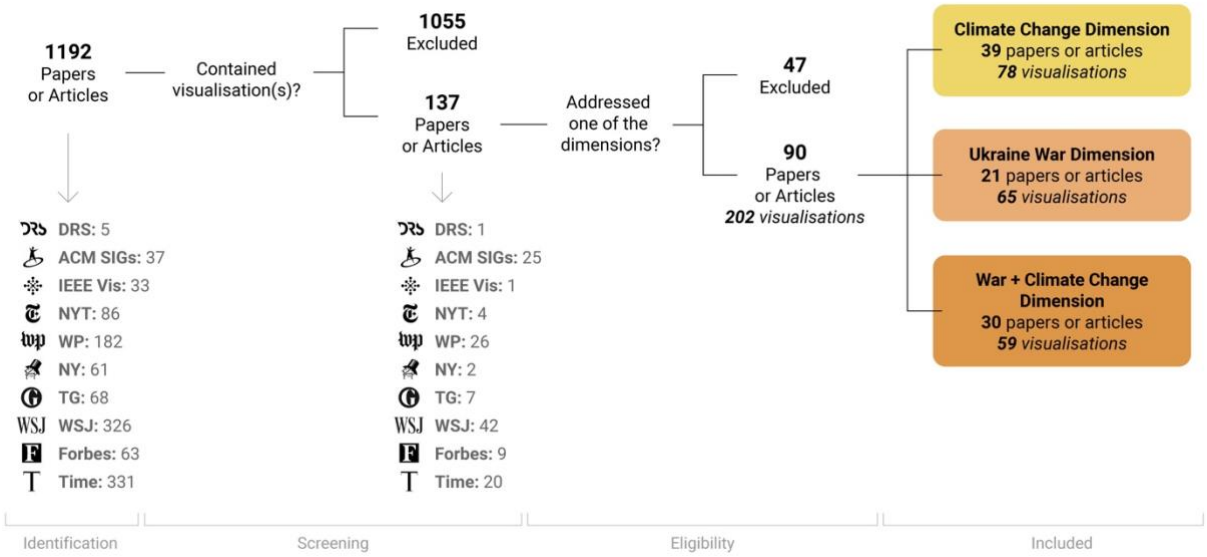

Figure 1. Flow diagram of the systematic review methodology.

3.2 Analysis

Our survey aimed at understanding how the war in Ukraine has been associated with climate change, and how this topic has been visualised. Therefore, in the Analyze phase, we examined each of the 137 entries to understand if and how they mentioned climate change or the war in Ukraine. To accomplish this, we used thematic analysis (Braun & Clarke, 2022) to read through the gathered articles, how they mentioned the selected terms, and classify them as: a) Climate Change dimension; b) Ukraine War dimension; c) War + Climate Change dimension (connecting both dimensions). We discarded 47 results that did not fit in either of the dimensions. We further analyzed if the terms were mentioned "in passing" or had some weight in the article's discussion. For example, (Tabuchi & Migliozzi, 2022) mentions climate change, or (Davanian & Faloutsos, 2022) mentions the invasion of Ukraine. Still, these dimensions are not one of the focuses of the discussions, so they were not considered as uniting both issues and were instead classified as focusing on one dimension. This refinement resulted in a data set of 90 articles or papers that contained 202 data visualisations (Fig. 1).

4 Findings

The findings of this study result from three main research questions probing how the connection between the Ukraine war and climate change has been visualised. Firstly, after one year of the war, how have the research communities and the broader media linked the war to climate change (RQ1)? Secondly, how was this connection visualized (RQ2)? And finally, what can we learn from the approaches so far, and what can we propose for future work (RQ3)?

We conducted thematic (Braun & Clarke, 2022) and formal (Chandler & Munday, 2011) analysis of the data visualizations for the War + Climate Change dimension. Our intention was to see what patterns emerged from the content explored but also to better understand how the visual information was

organized and, therefore, how the content was formally communicated. From this analysis, the following patterns emerged: (i) a clustering of the visualisations around the topic of Energy; (ii) use of limited visualisation types; (iii) limited design strategies; and (iv) the limited use of narrative. We describe each one in detail below.

4.1 Visualisations topic clustering

In all three dimensions, the topic distribution is greatly influenced by the high number of visualisations found in The Wall Street Journal (70), which predominantly focuses on *Energy* (35) or *Finance/Commerce* (21) (Fig. 2). This suggests that economic factors play a significant role in both issues. However, apart from this influence, there is a noticeable difference in focus. In the Climate Change dimension, the most explored topic is *Weather* (28), focusing mainly on extreme weather events and temperature increases, indicating that these severe manifestations are commonly used to illustrate the consequences of climate change. On the other hand, the Ukraine War dimension, the one with the least variation of topics, focuses on *Digital infrastructure* (33) – all from the five ACM SIG research papers –, and *Fossil Energy* (13). This result indicates that the conflict has implications for the use and security of digital technologies, and the research community used this context to better understand its complexity and resilience.

Most articles for the combined War + Climate Change dimension have visualisations related to either *Energy* (37), with a considerable preponderance on *Fossil* (24), or *Finance/Commerce* (10). These are followed by *Emissions* (6), and a small representation of other topics. The WSJ influences this dimension particularly. Of the 59 visualisations, 35 are from this venue, all related to *Energy* (22) or *Finance/Commerce* (7), except *Emissions* (4), *Weather* (1), and *Territory* (1). Therefore, the influence of the war on the energy sector has been one of the most explored sides of the conflict. *Fossil* is at the forefront, and of note is that this result was pushed by a financial sector venue (WSJ), as illustrated in Fig. 2. The exposure of the dependency on Russian energy imports and the push towards renewable energy has been one of the consequences of the conflict. It has been much linked to climate change and building resilience.

Even though with less representation, the war seems to have also brought to the forefront the debate about *Food* security (two visualisations each for the War dimension and War + Climate Change dimension). The importance of Ukraine in grain exports and the consequences of its disruption, particularly in African countries (Cohen, 2022), has highlighted a problem that climate change has aggravated for years.

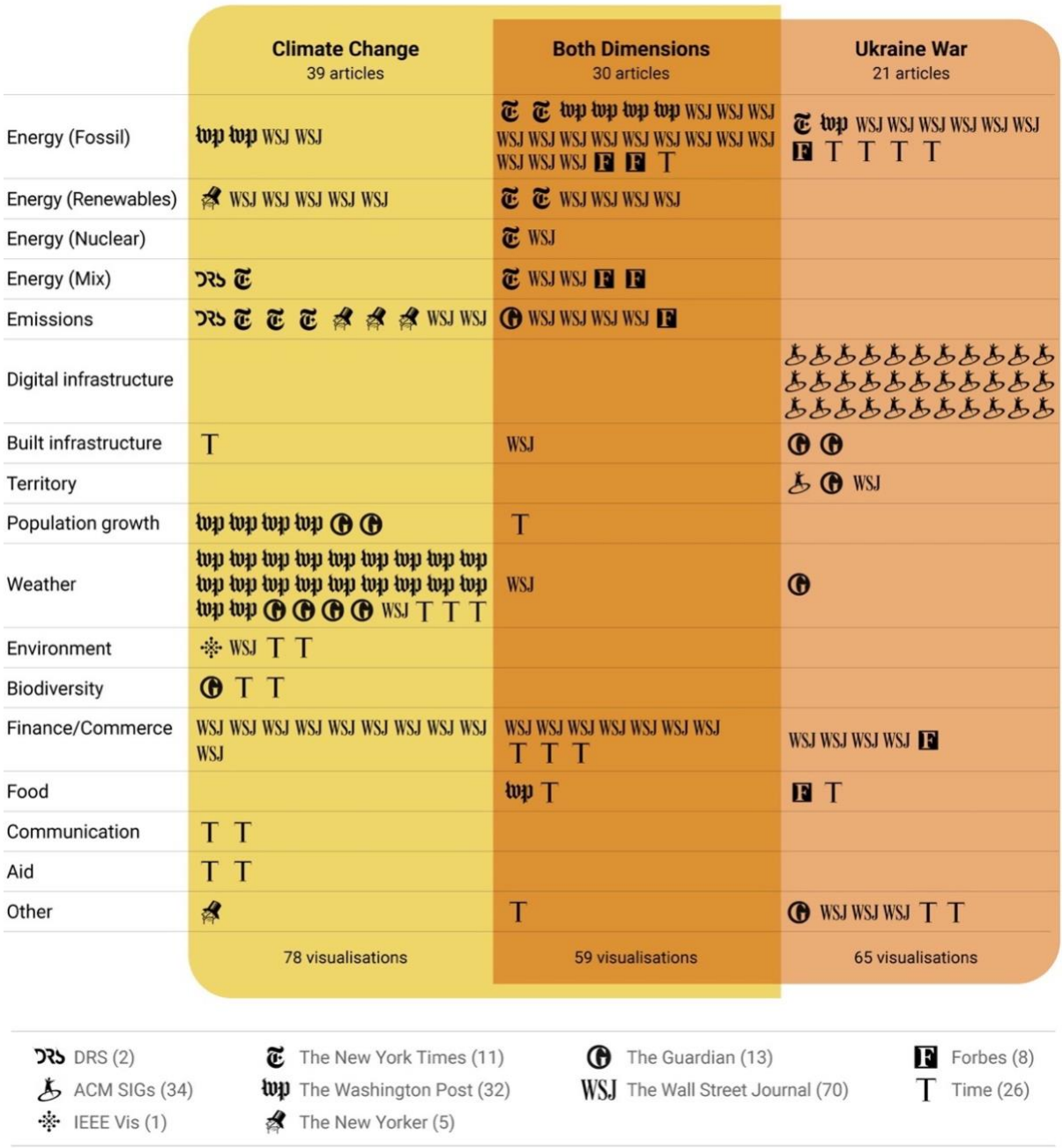

Fig. 2 - The final dataset comprises 90 articles with 202 visualisations. Here we present the visualisations (by publication venue) within each dimension, organised by topic.

4.2 Limited visualisation types

Within the articles addressing the War + Climate Change dimension, the great majority of data visualisations fall within two chart types (Fig. 3): bar charts (23) – a chart that uses either horizontal or vertical bars to display numerical comparisons across categories – or line graphs (21) – used to show quantitative values over a continuous interval, normally used to demonstrate trends and data changes over time. This tendency is evident through the two most explored topics – *Energy* and *Finance/Commerce*. Of the 48 visualisations, 39 fall within one of these two chart types (Fig. 4).

The other chart types found, with much less representation, are distributed as follows: area graphs (5); maps (4); proportional area charts (3); donut chart (1); bubble chart (1), and a simple text chart similar to a Sankey diagram (1).

Fig. 3 - Examples of the chart types found for the visualisations (N=59) from articles of the War + Climate Change dimension.

4.3 Limited design strategies

The data visualisations corpus showcases a consistent but limited use of design strategies. From the 59 visualisations, 26 are static. The remaining 33 use simple interaction strategies focused on hover highlighting / details (31) (e.g. (Joselow & DeBonis, 2022)), or animation on scroll (2 from one article (Kaplan et al., 2022)). The latter is the only article that connects the text content and the user's progression with the visualisations through animation. Besides being more engaging, it effectively connects the text with the data visualisation.

Furthermore, none of the interactive visualisations uses design elements to highlight their use of interactivity – such as markers for interactivity or tacit tutorials. Visualisations presented in the same article (Puko & DeBarros, 2022), of which one is static and the other is interactive through hover details, bear no apparent difference between the two before hover.

Regarding visual design, the great majority of the visualisations follow very straightforward representations of the data (as exemplified in Fig. 3). Six present small text annotations (e.g. (Worland, 2023)), and (Broughel, 2022) uses photography within a donut chart. Overall, the design strategies encountered in the examined corpus are consistent in their simplicity and directness.

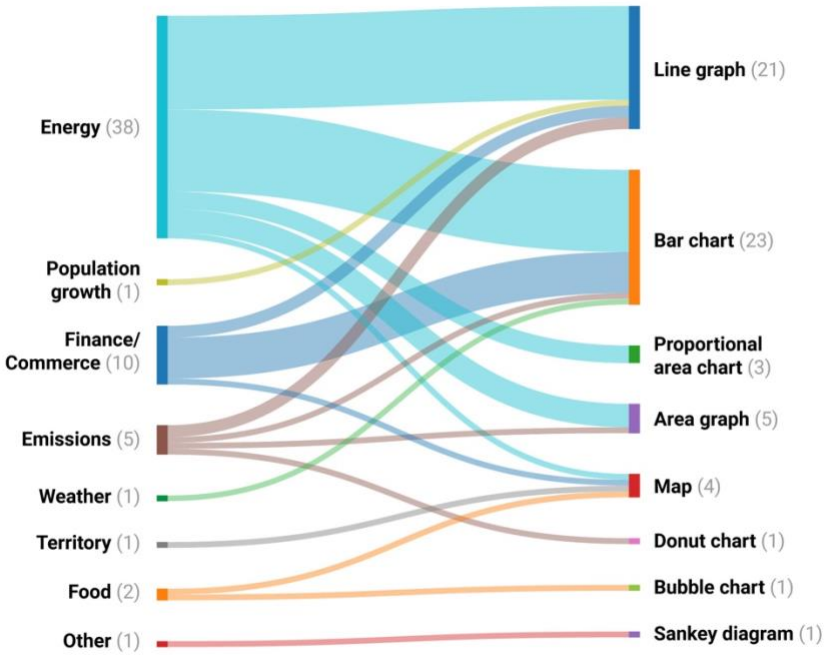

Fig. 4 - Visualisations (N=59) from articles of the War + Climate Change dimension, relating the topic of each visualisation with their chart type.

4.4 Limited use of narrative

The data visualisations analysed only illustrate a particular aspect of the overall content of the articles. For example, one article (Barone, 2022) connects oil companies' massive profits with their lack of investments in climate-related initiatives. The argument in the text is diverse, but there is only one data visualisation about stock buyback authorizations. Another article (Cohen, 2022) exposes the complex issue of famine in East Africa and its dramatic humanitarian consequences. Still, the only visualisation is an impersonal choropleth map showing the areas' level of food insecurity.

Many visualisations from our corpus are being used as complements of the text, and often lack information which is only found in the text of the article. For example, one chart (Buchholz, 2022) shows data in units of energy called *exajoules*, with no information about the meaning of this measure. Meanwhile, in the text, there is a comparison of its significance in percentage to global supply. The data visualisation assists in communicating the content of the text but is not a crucial piece of the communication exchange.

Our analysis revealed an absence of detailed and engaging data narratives explaining the crucial dimensions of war and climate change.

5 Discussion and future work

In this section, we discuss the design implications derived from the results of our analysis. We highlight what we learned from the visualisation approaches used so far, and what recommendations we can derive for future work.

5.1 Contextualising the quantitative data

When dealing with complex phenomena, like war or climate change, the data may feel impersonal and hence distant from the reader. As discussed in section 2.2, current climate change communication guidelines call for using stories and relation to local situations and communities more than statistics. The data should have meaning to the audience we are engaging with. Furthermore, communicators should avoid enhancing crisis-fatigue and climate-related anguish, that can lead to a lack of action and even psychological distress. Using strategies that contextualize the data can assist in giving a more hopeful and action-focused framing to the message, giving meaning by, for example, linking to personal experiences or community values.

In the following example article (Wolfe et al., 2022), climate change-related data is communicated through a personalization strategy (Fig. 5-A). The data story starts with the title, “You’re one in 8 billion”, and the visualisations are fundamental to creating this narrative. The user can input basic demographic information that is used to adapt how the data is showcased – linking you to the data presented. This strategy gives the quantitative data more meaning to the individual user by making the huge global numbers less abstract, being compared and connected to smaller and more personal measures. There is no manipulation of data – the set is simply treated and presented to maximize connection and interpretation.

Other design strategies such as annotations, visual highlighting, colour coding, or multi-messaging (Segel & Heer, 2010) can also be used to add qualitative layers of meaning to the quantitative data. These can visually link sets, and highlight particular points that are important to the data-story being communicated. Such strategies can be used within the conceptual framework of data humanism. This data visualization approach proposes to link the numbers to stories, knowledge, people, and behaviours. Adding layers of qualitative information to the quantitative data assists in translating “numbers into concepts we can relate to” (Lupi, 2017).

Moreover, from the results of our analysis, we see potential for future design and communication research to experiment with data visualisations that connect the two crises, adding context and meaning to the effects of climate change. A deeper connection to people’s day-to-day can lead to messages that encourage action, not hopelessness (section 2.2). The war’s impact on the energy sector and the increased debate surrounding the energy transition to renewables can be leveraged to shift the climate debate towards solutions and action.

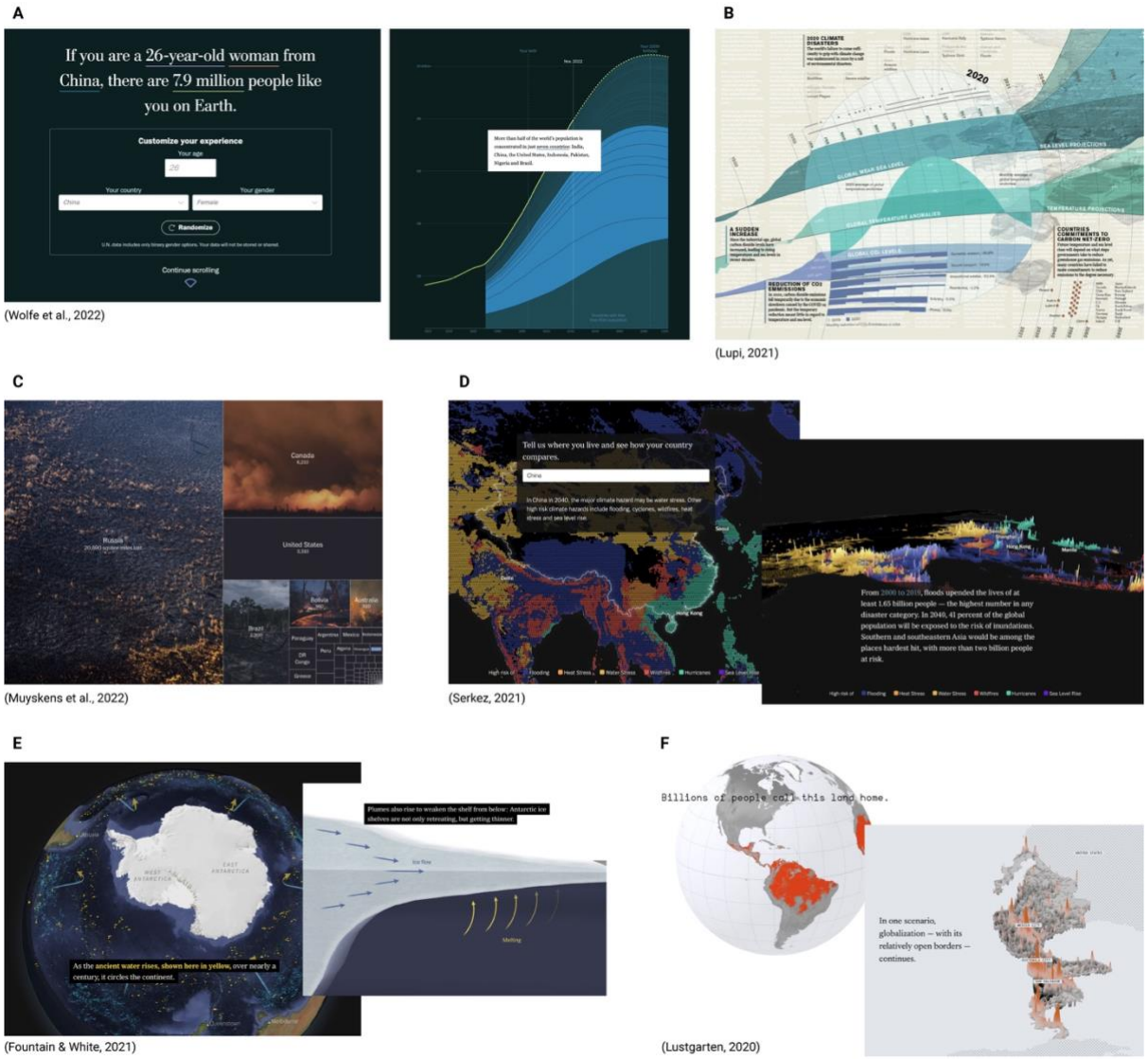

Fig. 5 - Data visualisation examples presented in the Discussion.

5.2 Exploring alternative data visualisation formats

Looking beyond standard chart models when working with data (Lupi, 2017) can be more visually engaging but also assist in communicating complex phenomena. Understanding different audiences' interpretations of and engagement with these alternative data representations can help identify strategies that point to stimulating paths for future work. This research can significantly impact climate change communication.

The work by Lupi (Lupi, 2021) about nuclear risk and climate change shows how layered visualisations can represent complex issues without oversimplifying the information (Fig. 5-B). These complex graphics don't follow a typical chart format and are enriched with several added layers of information that help emphasize or contextualize the quantitative data (as discussed in the previous section), creating very complex, yet informing and enriching experiences. This alternative format demands more consideration from the designer to ensure that the communication is effective, and more attention from the reader, but can lead to deeper engagement and understanding of the topics.

An article (Muyskens et al., 2022) found in the Climate Change dimension, uses photography of the burned areas within the data visualisations (proportional area charts), adding meaning and an emotional component to the numbers by illustrating the consequences of the wildfires (Fig. 5-C). The visualisation communicates an added layer of meaning through this visual treatment.

The results of our study highlight a very limited set of visualisation types used to illustrate the war and climate change joint phenomena. This gap points to an opportunity for exploring alternative and more diverse chart types. The complexity of climate change and the Ukraine war opens vast opportunities for more engaging data narratives that can be presented through more creative visual formats.

5.3 Using interaction to assist in communicating the data

Our study highlighted how, except for one (Kaplan et al., 2022), all articles visualised data as a separate companion to the written content, and not as a self-standing or crucial piece of information. This strategy is limiting, diminishing the impact that digital data visualisations can have when informing and engaging audiences on its own visual grounds. Visual design can convey meaning instantly without the mediation of language. This aspect is fundamental in communicating complex ideas effectively.

The following articles (Fountain & White, 2021; Serkez, 2021), when informing the readers about a certain country's climate risks, animate the country's map through the user's scroll (Fig. 5-D and E). The visualisations are accompanied by small annotations of text that appear as the visualisations change, creating a sequential presentation of the information that is easily absorbed and less overwhelming than asking the reader to connect the separate text and the visuals by themselves. The impactful visualisations immediately catch the reader's attention and are indispensable elements of the article's argument. Unlike static infographics, the animated infographic about ice shelves in (Fountain & White, 2021), controlled by the user's scroll, illustrates the information incrementally and sequentially, making it easier to understand (Fig. 5-E) as "information visualisation is not only about visual elements but also about interaction" (Mauri & Ciuccarelli, 2016). Mauri and Ciuccarelli highlight that these techniques "support the creation of exploratory paths, providing the user a step-by-step introduction into the complexity of the analysis." Interaction in data visualisations can be used to showcase extra points of data – as is the case in the data set analyzed – but can also assist in interpreting and guiding the narrative.

Our study highlights the importance of interaction tactics such as *markers of interactivity* (pointing to interactive elements and guiding the user), *filtering*, *timelines*, *transitions*, etc., to fruitfully engage audiences in understanding and connecting with the data, avoiding information overload, hence disengagement with the topic. This is of paramount importance in climate change communication.

5.4 Explore narrative tactics for more engaging visualisations

The data visualisations analysed use a limited set of design strategies. Designers should consider an integrated approach that uses visual language, data content, the story communicated with the data, and the narrative (visual and conceptual). They should "question the impersonality of a merely technical approach to data" (Lupi, 2017). (Segel & Heer, 2010) discuss the potential of narrative visualisations through the use of *visual narrative tactics* – (i) visual structuring, (ii) highlighting, and (iii) transition guidance – and *narrative structure tactics* – (i) ordering, (ii) interactivity, and (iii) messaging. These strategies can be used to guide the reader and assist in drawing meaning.

An article in The New York Times about migration caused by climate change (Lustgarten, 2020) uses some of these strategies with great effect. The narrative starts with a simple, greyscale Earth globe that only comes alive as the user scrolls, as a continuous animated slide show (Fig. 5-F). The user controls the "speed" of the narrative, but the interaction with the content is limited, in a balance between an author-driven and reader-driven story (Segel & Heer, 2010). This animated data map grabs the reader's attention and sets the stage for the article's argument. The data is further contextualized and humanized through photographs of the affected people. The data visualisations are used throughout the article as integral elements to communicate the information. All the visual and textual elements are designed to tell a coherent and engaging narrative. The interactive visualisations discussed above (Fig. 5-A, D, E) are also great examples of the use of data narratives, with the visualisations being a dynamic and indispensable part of the content.

(Segel & Heer, 2010) focused their study on narrative visualisations that "contained clear sequences of narrative events, a diversity of visualisation genres (e.g., flowcharts, slide shows), and a range of interaction strategies (e.g., filtering, timelines)". Visualizing complex phenomena, like climate change, the war, or the COVID-19 pandemic, holds opportunities to employ narrative visualisation strategies to depict complexity without compromising data richness and personal meaning to various audiences.

6 Limitations of the study

Platforms with an English version restricted the venue selection, so these criteria eliminated highly read platforms such as Dainik Bhaskar (India) or Cankao Xiaoxi (China). Furthermore, even though the venues analysed are global in scope and some of the most read worldwide, they originate from the USA or the UK and can lean towards a more highly educated readership. Future work should broaden the analysis to a more diverse range of venues and target audiences.

Regarding the implications proposed, they need to be tested when connected to this topic. However, previous research has pointed to the efficacy of adding interaction to data visualisations and linking data to layers of qualitative information to add meaning and enhance engagement (Ferreira et al., 2023). Another aspect to consider regarding the data visualisation proposals is the risk of less accessibility, a topic deeply debated within the *dataviz* community (e.g. (Aljasem, 2020; Fan et al., 2023)). This aspect should be carefully considered when creating any data visualisation project.

7 Conclusion

As climate change continues to be the most prominent global challenge we face as a society, learning more about the communication strategies being used to engage audiences with the topic is tremendously important. Current socio-political events affecting people and the environment, such as the Russia-Ukraine war, can assist in giving meaning to the frequently abstract climate data. With this study, we set out to understand how the Ukraine war and climate change have been connected and visualized. The purpose was to learn from these strategies and suggest implications for future work.

The results from our study contribute to the design and information visualisation community by suggesting avenues for future research into climate change data visualisations, considering: a) contextualising the quantitative data; b) exploring alternative data visualisation formats; c) using

interaction to assist in communicating the data; d) explore narrative tactics for more engaging visualisations. Additionally, future studies can examine the impact of audience engagement with alternative data representations and how these visualisations can influence climate change communication.

By applying these insights and recommendations, researchers and designers can explore communication strategies to address complex phenomena like climate change, fostering increased awareness and stimulating action. Within the vast amounts of war and climate change data, there is an opportunity to design more engaging data narratives, increasing the understanding of the information and engagement of its audiences.

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