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Scenarios and Decision Support for Security and Conflict Risks in the Context of Climate Change

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Abstract

Purpose of Review Concerns about conflict induced by climate change have captured the attention of policymakers, but the scientific foundations for these claims are contested. This review briefly examines different ways that the future of conflict risk in the context of climate change has been characterized, with a particular focus on scenarios.

Recent Findings Scientific consensus remains low over the role of climate change as a driver of conflict risk. This is rooted in disagreements over the interplay of socio-economic and climatic factors contributing to conflict risk. There is less controversy that climate change vulnerability, coupled with inappropriate adaptation solutions (i.e., maladaptation) in places where conflict dynamics already exist (e.g., high levels of inequality, marginalization, and political rivalries), tends to increase existing tensions. Additionally, scenario analysis has had an unremarkable presence in recent literature, with more attention being paid to knowledge-accumulation challenges for conflict research.

Summary Conceptual innovations from the wider climate change research community for the meaning of climate change risk, as well as for scenario research design for risk assessment in the context of climate change, may be vehicles for knowledge accumulation within the fields of security and conflict research.

Keywords Scenarios · Epistemology · Systems analysis · Complexity

Introduction

Consensus remains low over the role of climate change as a driver of conflict risk [1•, 2•, 3•]. Key questions are whether climate change increases risk of violence (directly or indirectly) as well as whether climate-induced economic disruption [4] or migration [5] will pose security threats to states or people. Core scholarship on conflict risk is empirical [6, 7•], but various scholarly disagreements thwart knowledge accumulation [12–14]. These include disagreements over terminology [8•], appropriate ways to approach problem definition (e.g., ontology [3•, 8•, 9] and scope, or scale [10, 11]), as well as whether causal mechanisms affecting conflict risk should be articulable [7•, 12].

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Conflict is multi-faceted, occurring within and between states, and it is subject to multiple social and material drivers such as educational attainment, resource availability, and power dynamics [1•, 2•, 9, 11]. Some argue that the preservation of peace is essentially a contextual, local affair based on community norms [15, 16]. It has also been argued that insufficient research is being performed on peaceful societies avoiding conflict, including those facing climatic stressors [2•, 8•, 17]. In short, open questions remain on why some societies under similar climatic conditions breakout into violent conflict while others do not.

Ever since its Fourth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) has recognized three "pillars" of knowledge for how the physical science of climate change is understood [18, 19]: observations, theory, and computer simulation. In comparison, conflict research under climate change is still characterized by disagreements over what observations are meaningful (e.g., quantitative datasets with global coverage versus qualitative contextual data [12]), what theory may be applicable, and what characterizations of the future, or modeling approaches, are meaningful or plausible.

There are multiple approaches to characterize the future [20], and this review focuses on scenario analysis since it is commonly used for decision support in various fields. Scenario analysis often traces its origins to military planning (see e.g., [21]), and policymakers in various spheres are hardly strangers to entertaining scenarios. Scenarios can be qualitative (i.e., narrative), quantitative (e.g., modeled statistically, simulated through agent-based modeling), or some blend of the two. Although scenarios are not predictions, they do aim to reveal information that can be useful for policy decisions, such as ranges of plausible benefits and costs or conditions expected to result in policy failure. However, as will be discussed in this review, scenario analysis may be capable of more, especially for helping the fields of security and conflict research improve knowledge accumulation, or for inspiring local efforts around resilience to climate change or to conflict.

This review examines analyses characterizing the future of conflict risks in the context of climate change as well as directions for future research. It considers the roles scenario analyses have generally played in decision support, as well as analytical methods that can be employed.[1] Additionally, recent conceptual innovations in the meaning of climate risk [24], as well as in research design for climate risk assessment and climate policy analysis more broadly [25•], point to new directions for scenario analyses of conflict risks.

Challenges for Decision Support on the Topics of Security and Conflict in the Context of Climate Change

Generally speaking, policy-making is a pragmatic exercise, meaning that policymakers are ultimately concerned with the practical consequences of their decisions [26]. Since the future is undetermined, policymakers employ heuristics or tools to arrive at their conclusions. The fallibility of heuristics for anticipating time-lagged, indirect, or long-term consequences is well-established (see e.g., [27]), so experts work to raise the quality of informational inputs to decision-making [26, 28, 29]. For policy analysis, such inputs include characterizations of future conditions in some way, e.g., scenarios, projections, or probabilistic futures [20].

To be valuable for decision support, scientific input must be policy-relevant, politically legitimate (meaning that knowledge users have confidence in the analytical approach), and scientifically credible [26, 30]. However, critiques have surfaced that findings from the social sciences for climate change research [31], and conflict research in particular [3•, 13], may not meet these criteria. Social science research appears to suffer from problems with knowledge accumulation due to limited use of synthetic analytical techniques such as meta-analysis or realist reviews [32]. In turn, insufficient knowledge accumulation may diminish the scientific credibility of recommendations based on limited collections of case studies or highly aggregated datasets [5, 12, 16].

This raises questions about what the objectives should be of scenario analyses for conflict research in the context of climate change. Should they be to arrive at policy recommendations that will reduce harms, losses, or risks? This may be the ultimate goal, but where the knowledge foundations are too imprecise or otherwise insufficient, a more modest goal—such as to develop shared understanding of system vulnerabilities—may be more appropriate. Below, "Fitting Approaches for Characterizing the Future to the Primary Purpose of Decision Support" introduces three primary purposes for characterizing the future of conflict in the context of climate change: risk reduction, learning, and program or policy design. Subsequent subsections elaborate the implications that alternative objectives have on problem framing and research design.

Fitting Approaches for Characterizing the Future to the Primary Purpose of Decision Support

Scenario analysis is one approach for characterizing the future, and it can be used for multiple purposes (see, e.g., [21]). For this reason, the environmental modeling literature recommends that models used for characterizing future conditions be "fit for purpose" [33]. Generally speaking, for decision support, studies that characterize the future tend to focus on one of three objectives: (1) risk reduction; (2) modeling for understanding; or (3) modeling for design, specifically the design of a policy instrument or program intervention. Effective modeling for risk reduction or design relies upon knowledge accumulation, which may have been developed through successful modeling for understanding. However, for decision support, modeling for more than one objective is not always better; at times, aiming for all three may be overkill. Additionally, as analysts turn their focus to each of the three purposes, this bears implications for different approaches to problem framing, informational needs, and analytical methods for characterizing the future. Hereinafter, "Alternative Objectives for Characterizing the Future in Decision Support" contrasts the three objectives along with the analytical approaches that best fit their respective purposes. "Alternative Approaches to Scenario Analysis" contrasts approaches for scenario analysis in particular, namely qualitative scenarios versus different means for pairing qualitative and quantitative scenarios.

[1] The latter are important to consider when making sense of any wicked problem [22]. This is because choices for analytical approach affect how the problem is framed, constrain what information (including stakeholder perspectives) is deemed relevant, and ultimately, what policy options will be considered [23].

Alternative Objectives for Characterizing the Future in Decision Support

Characterizing the Future for the Purpose of Risk Reduction Risk is classically defined as the product of impact and probability. Thus for this style of foresight, which includes the provision of early warning of events, or some kind of anticipatory response, prediction is an aspiration. Reasonably accurate predictions of both impact and probability are desired, which demands knowledge aggregation (e.g., sufficient data for statistical power, see [34•, 35•] for examples; or (expert) consensus on causal mechanisms). A potential limitation is that this style of analysis is based on historical observations. With concerns that climate change will push natural and human systems to break away from historical precedent, this may mean that the predictive power of such studies will be limited or diminish over time [2•].

Characterizing the Future for the Purpose of Understanding However, knowledge aggregation may be unrealistic (due to data limitations or low consensus among experts) or irrelevant (because the problem is contextual or novel). Under such circumstances, models may be developed and analyzed to explore the complexity of system interrelationships, or relationships between systems (e.g., the climate system and a socio-political system). As elaborated further below in "System-Theoretical Modeling for Security and Conflict Research," where consensus is lacking, deliberate efforts to explore alternative implications of differences of (expert) opinion can be thought-provoking and informative [36, 37]. Such efforts may also be helpful for building political legitimacy around a study's results, as stakeholders or audiences with different perspectives can see that their views were incorporated [38]. A policy analysis of the US Terrorism Risk Insurance Act (TRIA) by the RAND Corporation provides a good example of how political legitimacy can arise from modeling practices that include alternative political views [39]. In this case, political parties held differing perspectives about many issues surrounding TRIA, including the likelihood of another large-scale terrorist attack and the capacity of the private insurance industry to absorb losses. Rather than employ expert judgment to describe a best-estimate future or consensus views, RAND simply incorporated the alternative views of politicians into their model runs to isolate what differences of opinion (or "open questions") mattered most to the conclusion that TRIA might be a waste of taxpayer money. Once RAND presented its results (that only three out of 17 uncertainties in play truly mattered, and that under most conditions, TRIA would save taxpayers money), their conclusions encountered little resistance because alternative views of different decision-makers were incorporated.

Characterizing the Future for the Purpose of Design "Design thinking" [40] is a particular approach to problem-solving. To arrive at the best designs—which include policies or program interventions—designers avoid linear models for problem-solving (e.g., [41]). Instead, what is embraced is iteration, where designers repeatedly cycle through phases of problem definition (or scoping), divergent (or exploratory) thinking, convergent thinking to focus on a few implementation options, and prototyping/testing of options before committing to a final design [42]. It is expected that the process of design thinking will involve doubling-back through these phases, as for example, a failed prototype may cause a designer to revisit assumptions made during problem definition [43]. In short, the goals of characterizing the future for the purpose of design go beyond enhancing understanding to also include learning from experimentation with a model.[2]

Design has emerged in the environmental modeling literature as a key objective because continued environmental degradation (such as climate change) in the face of increased scientific understanding (i.e., knowledge accumulation) suggests that the linear model of expertise has largely failed [41]. This has inspired a participatory turn [45, 46], as providing policy-relevant information may not be enough; instead, what may be more useful are learning environments for practitioners, stakeholders, and experts (i.e., forums for co-producing knowledge). Since learning is an inherently social process, this objective bears implications for what approaches and methods for foresight should be used. Participatory approaches to modeling show promise, as they aim for co-learning or co-management between experts and stakeholders. Practitioner and stakeholder engagement should occur early and often throughout the design-thinking cycle.

Alternative Approaches to Scenario Analysis

There are a number of recent reviews of scenario analysis [47–49]. The field is characterized by a diversity of approaches and methods, so selecting the most appropriate approach will be a function of the objectives for characterizing the future (see "Alternative Objectives for Characterizing the Future in Decision Support" above) and the time and resources available (e.g., Does an appropriate simulation model exist?). Approaches summarized below are presented in the order of degree of modeling rigor, which corresponds roughly to a spectrum of qualitative versus quantitative scenarios. The main benefits of the approaches that are the least rigorous are that they are fast and possibly require a smaller budget. The most rigorous approaches provide the highest degrees of specificity, transparency, and make use of simulation or statistical

[2] A related concept for building adaptive capacity is adaptive management [44], which may also employ models for the purpose of "testing" an implementation or policy idea (a "prototype").

models. However, such models may take years to develop if they do not exist already.

Qualitative Scenarios These scenarios are commonly presented as narratives and influence diagrams (e.g., mental models). Such scenarios may be standalone because detailed simulation or statistical modeling is unavailable or such projections are not needed for decision support. The least rigorous way to develop qualitative scenarios is through subjective judgment, including the judgments of experts. Nevertheless, subjective judgment may be appropriate when the goal of the scenario analysis is exploration of system behavior. Such exploration can raise awareness and inspire exploration of possible corrective actions. Subjective judgment may also be appropriate when information for decisions must be produced and conveyed under time constraints that do not permit work with formalized models. However, the primary limitation in relying on subjective judgment is the activation, or reinforcement, of cognitive biases [27, 50], especially overconfidence [51].[3] Proponents of qualitative scenarios note that narrative acts as a persuasive tool [21, 52], but activating such biases in the name of persuasion can have undesirable effects. Selby and Hoffman argued that the field of conflict and security in the context of climate change did not originate from scientific research [53]. Instead, it originated from qualitative scenario studies produced by consultants and defense policy thought leaders. In spite of scientific uncertainties over whether it would be reasonable to conclude that climate change will drive conflict, this hypothesis has had staying power in the policy community.

To temper undesirable bias, there is a more rigorous method for developing qualitative scenarios called cross-impact balances, or CIB [54]. CIB employs systems theory to derive qualitative scenarios. An example application is discussed briefly below in "System-Theoretical Modeling for Security and Conflict Research", which shows that CIB involves building a formal, but simple, model [55] and employing a factorial experimental design. CIB is appropriate when the goal of scenario analysis is not only exploration of system behavior but also minimization of overconfidence about system behavior, or "surprise". For example, a CIB retrospective of the IPCC *Special Report on Emissions Scenarios* found that high emissions scenarios were not inconsistent with high economic growth [56]. In other words, from a system theoretical perspective, the dirty coal-powered growth trends occurring in China since the year 2000 could have been anticipated. Developing such system-theoretical models with CIB make it a more time- and labor-intensive method compared to subjective judgment, but it is no more intensive than other research projects. It has been argued that, epistemologically, scientists performing policy-relevant research have little reason to choose subjective judgment over formal approaches like CIB for developing qualitative scenarios [57].

Qualitative-Quantitative Scenario Pairings When qualitative description of alternative futures does not provide sufficiently detailed information for decisions, quantitative scenarios may be desired. Quantitative models can provide estimates for economic benefits, morbidity, or mortality rates, and so forth. For decision support, all quantitative scenarios employ qualitative explication of some type to communicate results to non-specialists. Among the three approaches to qualitative-quantitative scenario pairings summarized below, the key differences are whether qualitative explication is used to drive quantitative modeling, and whether the modeling employs factorial or Monte Carlo experimental designs. All approaches summarized below assume the availability of an appropriate statistical or simulation model.

The least rigorous way to present a qualitative-quantitative scenario pairing is to provide qualitative explication of the results of quantitative modeling based on an experimental design that is neither factorial nor Monte Carlo. This means that the modeler exercised their judgment to analyze some limited number of model runs they believed would be sufficiently comprehensive. The weakness of this approach is similar to that of developing qualitative scenarios through subjective judgment; the overconfidence heuristic of the scenario analyst has not been sufficiently guarded against. In addition, qualitative explication grounded in little more than explaining results may slip into speculation about their significance. Lewis [21] reviewed a number of influential human security studies of this type based on climate modeling [58, 59]. She found their conclusions about increased security risk to be questionable because the studies became opaque about the socio-economic mechanisms responsible for risks. This likely reflects that the qualitative explications reached beyond the bounds of what could be justified from the scope of the original models.

A more rigorous qualitative-quantitative scenario pairing is story and simulation (SAS), where qualitative scenarios, as discussed above, are developed first then interpreted as quantitative inputs for quantitative modeling [60, 61]. In contrast to qualitative explication of some limited number of model runs, SAS grounds the assumptions for modeling in qualitative stories. The main benefit of SAS over qualitative explication is that a detailed narrative, consistent with the experimental design employed by the quantitative model, provides a compelling vehicle for communicating the motivation for the study as well as its results. For scenarios that play an organizing role for further research—such as the IPCC *Special Report on Emissions Scenarios* or the Shared Socio-economic Pathways (SSPs)—an additional benefit is that the qualitative and quantitative scenario components can be considered interchangeable. However, whether SAS provides more

[3] Examples of overconfidence include groupthink, "poverty of imagination," and wishful thinking.

epistemological benefits than qualitative explication depends entirely on how the qualitative scenario is derived [57]. If the story is developed through subjective judgment, the epistemological benefit of SAS compared to no-frills qualitative explication may be negligible. However, if the story is developed through formative analytical approaches [54, 55, 62], cognitive biases can be corrected to some degree, thereby improving the epistemological quality of both the qualitative and quantitative scenarios.

The most rigorous approach to qualitative-quantitative scenario pairing is scenario discovery [38] (also called vulnerability analysis [63]). With this approach, a policy proposal is assessed with a simulation model that is run a large number of times, ideally with a factorial experimental design (depending on model complexity, this results in hundreds to tens of thousands of model runs). In effect, the policy proposal is comprehensively "stress-tested" by the model to uncover circumstances (i.e., scenarios) where the policy fails. Scenario discovery is appropriate when there is sufficient consensus on (a) problem definition and (b) relevant policy options to test through simulation (see e.g., [64], which took its policy options from Shared Policy Assumptions [65•] related to the SSPs). Through this approach, it is important to note that what is "discovered" are simple qualitative scenarios describing circumstances for policy failure. This is in contrast to SAS and to qualitative explication, where qualitative scenarios mirror quantitative scenarios in some way.

Scenario discovery has two main benefits. First, due to its factorial experimental design, comprehensive exploration of system behavior is guaranteed (within the model boundary of course). Similar to the benefit of CIB for qualitative scenarios, comprehensive exploration is what minimizes overconfidence. Second, the scenarios that are discovered are policy relevant by definition, as they describe the circumstances under which policy will fail. In contrast, scenarios developed through all other methods can potentially be "tuned out" by stakeholders or practitioners who find them implausible. However, a limitation for scenario discovery is that it cannot comment on the likelihood of the scenarios discovered.

Future Directions for Research that Characterizes Security and Conflict in the Context of Climate Change

The Two-Part Scenario Framework for Exploring Simultaneous Climatic and Socioeconomic Conditions

The IPCC *Special Report on Emissions Scenarios* (SRES) presents alternative socio-economic scenarios as drivers of alternative emissions profiles [66]. This is consistent with the cause-effect relationship between economic activity (namely energy and land use) and atmospheric greenhouse gas concentrations. However, an important finding of the SRES is that alternative socio-economic scenarios can produce similar emissions profiles [66], and subsequent studies replicated this finding [67]. This means that a proper conceptualization of uncertainty propagation is not unidirectional (i.e., socio-economic scenarios leading to a spread in emissions profiles, which leads to a subsequent spread of temperature change projections [68]). Instead, it is bidirectional, where any particular emissions profile can correspond to both a spread of socio-economic scenarios and a spread of temperature change projections [69].

In parallel, the IPCC Special Report *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (SREX) presents disaster risk as the intersection, or co-occurrence, of particular socio-economic and climatic conditions [24].[4] Put simply, societies with more desirable socio-economic conditions (i.e., durable infrastructure, accountable governments, higher standards of living) will be more resilient to extreme weather events, natural variability in climate, and potentially climate change compared to societies with less desirable socio-economic conditions. This conceptual innovation, where risk is understood as the co-occurrence of socio-economic and climatic events, is more consistent with scenario analyses searching for low-probability but high-impact "perfect storms" [71]. Studies taking a more traditional, probabilistically-driven view—whether they be risk assessments or forecasts—often discount such scenarios because of their low probability.

These key re-framings—that uncertainty propagation from an emissions profile is bidirectional, and that risk is determined by the co-occurrence of socio-economic and climatic events—lead the scientific community to develop a new scenario framework. Emissions profiles, which are projections of global greenhouse emissions for the remainder of the century measured in units such as gigatonnes of carbon (GtC), are captured by Representative Concentration Pathways, or RCPs [72]. Socio-economic scenarios, which describe alternative socio-economic futures both qualitatively and quantitatively (e.g., projections of population growth, economic growth, hectares of land used for growing food) are captured by Shared Socioeconomic Pathways, or SSPs [73].[5] What the new scenario framework means for conflict risk research is

[4] Research on extreme weather events is also moving in this direction [70].

[5] In contrast to the SRES, socio-economic data for the SSPs are fairly detailed. This was purposely done to make the SSPs more useful for assessing climate risk. Qualitative scenario factors include details about demography, quality of life (i.e., human development), economic characteristics, consumption patterns, policy orientations, institutional effectiveness, technology use, and resource availability. Quantitative scenario projections include population, GDP, urbanization, and emissions profiles for air pollutants.

that investigators must weave climatic and socio-economic threads back together in their study designs [25•, 74].[6] This is consistent with arguments made by Lewis [21] that scenario analysis of risks to human security should embed projections for climate change within socio-economic contexts. With the new RCP-SSP framework, this can be as straightforward as utilizing RCP projections [75] along with socio-economic data available in the SSP literature, which is either qualitative [76•] or quantitative [77].[7] Some care should be taken, however, to ensure that whatever RCP-SSP combinations are assumed are indeed compatible [78•]. For instance, research has confirmed that the SSP assumptions for a "Sustainability" future (SSP1) do not produce the high emission trajectory, RCP8.5.[8]

Additionally, similar to an open-source computer code, the SSP framework invites further contributions from the scientific community through new information entering the literature. Some examples include spatially explicit population projections for the globe, coastal areas, and specific geographic regions [79–81]. Another example comes from conflict research, where conflict risk is forecast at the country level for each of the five SSPs [82•]. Hegre et al. developed a statistical model of the historical effect of socioeconomic variables on country-level incidences of conflict to find that SSPs characterized by high socio-economic challenges to adaptation—such as slow economic growth, large populations, and poor human development in developing countries—are futures with the highest conflict risk. However, Hegre et al. caution that their analysis does not reflect possible additional effects of climate change on conflict risk, as their study does not include the RCPs.

[6] Note that RCPs and SSPs specify macro-level boundary conditions for anthropogenic forcing on the global climate system and global trends for alternative socio-economic outcomes, respectively. Investigators with research questions that focus on more meso- or micro-scales must "extend", or elaborate, on the macro-level information provided by RCPs and SSPs. For instance, if potential impacts due to changes in precipitation are of primary interest, the investigator must consult multiple climate model scenarios driven by a particular RCP. Similarly, if the study is focused on a sub-continental geographical area, country-level socio-economic outcomes consistent with the global trends of SSPs may be more informative than utilizing global SSPs. In short, the RCP-SSP framework acts as an anchoring framework to make heterogeneous impact studies more comparable.

[7] SSPs are qualitative-quantitative scenario pairings developed with the SAS approach discussed in "Alternative Approaches to Scenario Analysis". This means that quantitative SSP projections are simulated versions of the SSP narratives.

[8] There are four alternative RCPs, and their names refer to the strength of radiative forcing on the atmosphere (measured in Watts per square meter) by 2100. The RCPs are RCP2.6, RCP4.5, RCP6.0, and RCP8.5. This means that RCP8.5 represents over three times more radiative forcing on the climate system than RCP2.6 by 2100. The shorthand names of the five alternative SSPs (SSP1, SSP2, SSP3, SSP4, SSP5) are categorical in no particular order. Their longform names are more descriptive: Sustainability (SSP1), Middle of the Road (SSP2), Regional Rivalry (SSP3), Inequality (SSP4), and Fossil-fueled Development (SSP5). Readers interested in learning more about the RCPs and SSPs are strongly encouraged to consult the original papers and Special Issues in references [72–78].

At the time of this writing, Hegre et al. is the only example of conflict research engaging with the RCP-SSP framework. Future work can build on what they started by completing the conflict risk assessment with appropriate RCP-SSP pairings. Alternatively, future work could further contextualize the implications of RCP-SSP futures for particular places—for example, what does an RCP6.0-SSP1 future mean for Nigeria? What about an RCP6.0-SSP4 future?

A major benefit of aligning future research for conflict risk in the context of climate change with the RCP-SSP framework is that it supports knowledge accumulation for IPCC assessment [25•] and possibly for the field of conflict research. This is because the RCP-SSP framework provides a broad yet harmonized menu of socioeconomic and climatic assumptions, as well as boundary conditions for how assumptions can be combined for internal consistency. The framework aims for a balance between flexibility (to enable contextualization) and order, where the latter provides sufficient standardization to make very different studies comparable [83]. Of course, as discussed in "Introduction" above, open questions remain for conflict research on appropriate ways to analyze and interpret data as well as to develop theory. Such research must also continue, and "System-Theoretical Modeling for Security and Conflict Research" may help in this regard.

System-Theoretical Modeling for Security and Conflict Research

Multiple scholars have commented on the limitations of statistical models for drawing conclusions about conflict risk in the context of climate change, namely that such models cannot reflect the complex causal chains suspected to be relevant [3•, 12, 84, 85•]. This has led some to call for a systems view of security and conflict risk, as systems thinking may permit the flexibility needed to combine qualitative and quantitative findings to develop nuanced understandings [1•, 85•]. However, these calls for the future of security and conflict research stop short of providing much more than conceptual frameworks. This section revisits the system-theoretical method of CIB introduced in "Alternative Approaches to Scenario Analysis." It provides an illustrative example of how systems theory could be applied to support knowledge accumulation in security and conflict research as discussed in "Challenges for Decision Support on the Topics of Security and Conflict in the Context of Climate Change". CIB has been applied in a variety of contexts ranging from innovation processes, to energy transitions, to public health. However, it has not been applied to research on security and conflict. For this reason, in this section, the example introducing CIB is not specific to the climate-conflict nexus but instead is illustrative of how some relevant qualitative variables could be modeled. The section closes with commentary on opportunities for security and conflict research that would take best advantage of the CIB method.

A number of papers explain the CIB method in detail [54, 56], so a summary is provided here. CIB is a variant of cross-impact analysis, which "represents a schema for collating and systematizing … expert judgments, so as to make it possible to construct a conceptual substitute, however imperfect, for a wished-for but non-existent theory of how events affect one another in a multidisciplinary context" [86 p. 389]. CIB begins with a definition of the system, i.e., what scenario factors should be included. These are organized (i.e., collated) into matrix form (Fig. 1), where system factors that are influential are arranged in the row direction and system factors that are receptive to influences are in the column direction. The reader may notice in Fig. 1 that the system factors in the rows and columns are identical. This is by design, as the matrix form provides a schema for capturing interrelationships among scenario factors, where they behave simultaneously as drivers and receivers of system influences.

The numbers in the matrix reflect direct, state-specific pairwise relationships between alternative states of system factors. The numbers are recorded according to the cross-impact question,

> If the only piece of information given to you about the future of the system is that scenario factor X has the state x, would you expect the direct influence of X on scenario factor Y to be a hint that scenario factor Y has the state y (promoting influence, positive points assessed) or as a hint that scenario factor Y does not have the state y (restricting influence, negative points assessed)? (c.f. [54 p. 339])

Where no direct link exists between factors, zeroes are recorded in the matrix. Non-zero values indicate a direct link. The meanings of positive and negative numbers are similar to correlation coefficients. Positive numbers indicate reinforcing influences, while negative numbers indicate discouraging influences. Numerical values are ordinal, where larger numbers indicate stronger influences and smaller numbers indicate weaker influences. As discussed in, these numerical judgments can be elicited through participatory processes, where experts and/or stakeholders respond to the above cross-impact question and provide influences between states. Such participants can provide judgments individually or in groups. Alternatively, numerical judgments can be collected through meta-analysis, where judgments are interpreted from literature. Additionally, cross-impact judgments need not be derived solely from natural language statements. Judgments could also be based on findings from statistical analyses such as correlations or modeling outputs.

Only direct relationships are recorded in the matrix, as impact-score and impact-balance calculations (Fig. 1) automatically account for complex indirect influences. This is a strength of CIB, as the thorough accounting of direct pairwise relationships is used to account for complex indirect relationships that are not obvious. For example, in Somewhereland (Fig. 1), Foreign Policy exerts no direct influence on Distribution of Wealth (see the submatrix of zeroes at the intersection of row B, column D). Outcomes for Distribution of Wealth (column D) receive most of their direct influences from what political party is in power (intersection of column D and row A, "Government"), the state of the Economy (intersection of column D and row C), and the state of Social Values (intersection of column D and row F). Instead, Foreign Policy exerts an indirect influence on Distribution of Wealth, as Foreign Policy directly influences the state of the economy (intersection of row B and column C). This is just one example of the many indirect relationships embedded in the CIB matrix.

These multitudinous direct and indirect relationships are useful for investigating causal chains underlying specific scenarios. In Fig. 1, shaded rows isolate system influences that are

Cross-Impact Matrix "Somewhereland"	A.Gov A1 "Patriots party"	A2 "Prosperity party"	A3 "Social party"	B.FoP B1 Cooperation	B2 Rivalry	B3 Conflict	C.Eco C1 Shrinking	C2 Stagnant	C3 Dynamic	D.W D1 Balanced	D2 Strong contrasts	E.SCo E1 Social peace	E2 Tensions	E3 Riots	F.SoV F1 Meritocratic	F2 Solidarity	F3 Family
A. Government:																	
A1 "Patriots party"				-2	1	1	0	0	0	0	0	-2	1	1	0	0	0
A2 "Prosperity party"				2	1	-3	-2	-1	3	-2	2	0	0	0	2	-1	-1
A3 "Social party"				0	0	0	0	2	-2	3	-3	2	-1	-1	-2	2	0
B. Foreign policy:																	
B1 Cooperation	0	0	0				-2	1	1	0	0	0	0	0	0	0	0
B2 Rivalry	0	0	0				0	1	-1	0	0	1	0	-1	0	0	0
B3 Conflict	3	-1	-2				3	0	-3	0	0	3	-1	-2	-2	1	1
C. Economy:																	
C1 Shrinking	2	1	-3	0	0	0				-2	2	-3	1	2	0	0	0
C2 Stagnant	-1	2	-1	0	0	0				0	0	0	0	0	0	0	0
C3 Dynamic	0	0	0	0	0	0				-2	2	3	-1	-2	0	0	0
D. Distribution of wealth:																	
D1 Balanced	0	0	0	0	0	0	0	0	0			3	-1	-2	-2	1	1
D2 Strong contrasts	0	-3	3	0	0	0	0	0	0			-3	1	2	2	-1	-1
E. Social cohesion:																	
E1 Social peace	0	0	0	0	0	0	-2	-1	3	0	0				2	-1	-1
E2 Tensions	0	0	0	-1	0	1	1	1	-2	0	0				-1	0	1
E3 Riots	2	-1	-1	-3	1	2	3	0	-3	0	0				-2	-1	3
F. Social values:																	
F1 Meritocratic	0	3	-3	0	0	0	-3	0	3	-3	3	-2	1	1			
F2 Solidarity	1	-2	1	0	0	0	-1	2	-1	2	-2	2	-1	-1			
F3 Family	0	0	0	0	0	0	-1	2	-1	1	-1	2	-1	-1			
Scenario assumptions:		↓		↓					↓	↓		↓			↓		
Balances	0	3	-3	2	1	-3	-9	-1	10	-7	7	4	-1	-3	2	-1	-1
Maximum:		↑		↑					↑		↑	↑			↑		

Impact score of a state

Impact balance of a factor

Fig. 1 Illustrative example of a cross-impact matrix (reproduced from the manual for ScenarioWizard 4.02 with permission). Social factors in the row direction exert direct influences on factors in the column direction. Numbers in cells indicate the presence of direct links (non-zero values) or their absence (zeroes). Shaded rows isolate direct influences specific to the scenario [Prosperity Party controls Government, Cooperative foreign policy, Dynamic economy, Balanced wealth, Social Peace, Meritocratic values]. Numbers in the Balances row (bottom of figure) indicate the overall system response under this scenario. Downward- and upward-facing arrows indicate whether the highlighted scenario is a transient or equilibrium condition for the system particular to a specific scenario [Prosperity Party controls the government, Cooperative foreign policy, Dynamic economy, Balanced wealth, Social Peace, Meritocratic values]. Overall scenario feasibility is measured by combining the influences of each factor state to perform impact-score and impact-balance calculations. In the CIB matrix (Fig. 1), note that each factor state, in isolation, exerts particular influences directly on other factors. All factor states have this quality, and the impact-score calculations (bottom row of Fig. 1) indicate the overall "balance" of these simultaneous influences on the system. For example, the impact score pointed out in Fig. 1 (with a value of − 3) is determined by the sum of the shaded numbers in the columnar direction. For Somewhereland, the outcomes of Foreign Policy are generally influenced by what party controls the Government and the state of Social Cohesion. Under the scenario in question, when Social Cohesion is in a state of Social Peace, Government party agendas will dominate Foreign Policy outcomes. Thus, under this scenario, the calculated impact score specifically for the factor state Foreign Policy = Conflict is $-3 = -3 + 0 + 0 + 0 + 0$.

The impact score is an intermediary calculation for the impact balance, which is indicated in the bottom row of Fig. 1 with a bracket. The impact balance looks across all calculated impact scores for a particular scenario factor and flags the state that is the maximum (upward-facing arrow). The maximal impact score is significant because it indicates the overall system response (accounting for both direct and indirect influences) to the scenario. The bracket in Fig. 1 is for the factor Social Cohesion. Under the specified scenario, the Social Peace state has the maximal impact score of 4. The shaded numbers in the columnar direction are useful for explaining the causal chain that supports the outcome of Social Peace. For the Somewhereland system, the Prosperity Party has no agenda that stirs Social Cohesion in any particular direction. Similarly, a Cooperative Foreign Policy has no effect. This leaves the outcomes for the Economy, Wealth Distribution, and Social Values as more influential. Luckily, the positive influences of the Dynamic Economy and Balanced Wealth outweigh the negative influences of Meritocratic Social Values ($4 = 0 + 0 + 3 + 3 - 2$).

The final piece of information provided by CIB is a system equilibrium test for the initially assumed scenario, which is indicated by the alignment between the maximal impact balance states (upward-facing arrows) and the states of the scenario initially assumed (downward-facing arrows). Where there is misalignment (in Fig. 1, this occurs for the factor Distribution of Wealth), this indicates that the initially assumed scenario is a transient state for the system rather than an equilibrium. Under the scenario in Fig. 1, Balanced Wealth is not a compatible system outcome with the remainder of other states in the scenario. Again, the shaded columnar values provide the causal chain for why this is so. The Prosperity Party is opposed to Balanced Wealth, the Dynamic Economy gives rise to wealth imbalances, and Meritocratic Social Values foster a culture of competition (meanwhile Cooperative Foreign Policy and Social Peace have no effect). Thus was the system to find itself in this scenario (perhaps because of a regime change during an election, rapid technological change or economic development, a cultural history of meritocracy, or any combination of these things), it would not stay that way for long. The endogenous system adjustment would be to move toward wealth inequality. In contrast, for scenarios where all upward- and downward-facing arrows are aligned, this indicates that the scenario is a system equilibrium.

This example demonstrates key features of CIB that may make it useful for knowledge accumulation in security and conflict research in the context of climate change:

- Both quantitative and qualitative hypotheses for the interaction of socio-economic and climatic factors could be placed in one system-theoretical modeling framework. This is because the numerical judgments in a single CIB matrix could be based on both natural language statements about causal chains (i.e., from qualitative research) and quantifications about causal relationships (i.e., findings from statistical models)[9]
- Cross-impact matrices for CIB are sufficiently detailed that hypotheses for variable interactions can be state-specific (e.g., the effects of certain climatic stressors may be more pronounced when ethnic tensions are present [87])
- Through impact-score calculations, the cross-impact matrix provides a mechanism for uncovering complex causal chains that may be consistent with statistical model results
- Through impact-balance calculations, the cross-impact matrix assesses multiple hypothesized causal chains and identifies those that emerge from the full network of system interactions activated under specific conditions (i.e., scenarios)
- Complex systems have multiple system equilibria. Potentially, apparent disagreements in the literature may not be disagreements at all. Instead, they may reflect differences in state-specific interactions, or interactions that are present under particular scenarios (past or present). Through CIB tests for system equilibria applied to all scenarios possible,[10] CIB may uncover system equilibria that have yet to be observed [56].

[9] Of course, care must be taken to ensure that the meaning of natural language statements are comparable to statistical findings. Alternatively, a CIB analysis can be run multiple times to test the sensitivity of findings to alternative numerical cross-impact judgments that represent natural language statements.

[10] Existing CIB software can comprehensively search on the order of 10 billion scenarios [88]. For CIB analyses that exceed this number of possible scenarios, Monte Carlo approximations or techniques for analyzing large CIB matrices piecemeal [89, 90] can be used.

In short, CIB provides a concrete, flexible approach for developing simple system-theoretical models that can be manipulated as part of security and conflict research in the context of climate change. CIB has been used primarily for research related to energy futures [90, 91], but it may also be appropriate for security and conflict risk research in the context of climate change. Recent reviews of conflict research in the climate change context [85•, 92•] provide thorough collections of "expert judgments" on statistically significant relationships or proposed causal mechanisms for conflict risk. These collections are not collated or systematized, however, so they read like laundry lists. Instead, such lists could be used to specify some parsimonious list of factors for a CIB analysis. From reviews such as [85•], which includes a summary table of links found (or rejected) between climate change variables and violent conflict, numerical judgments could be derived for a cross-impact matrix. For security and conflict research, one could imagine building cross-impact matrices that may be more specific to particular spatial or timescales to investigate the implications of particular combinations of socio-economic and climatic factors.

A caveat is that CIB findings are wholly dependent upon the numerical judgments recorded in the CIB matrix. Software [88] provides tools to detect and correct bias in recorded judgments, but CIB is often employed because knowledge accumulation has been stymied to some degree. Theory may be incomplete for the complexity of the system, or there may be other reasons for low consensus in the field as discussed above in "Introduction." This means that numerical cross-impact judgments also carry some degree of uncertainty. The best practices for utilizing CIB include also eliciting the confidence of the judgments collected (not only the judgments themselves) and performing sensitivity analysis, such as through examining results from multiple versions of the CIB matrix (see, e.g., [56, 89]).

Discussion and Conclusion

Characterizations of the future for decision support may have three main objectives: to reduce risk, to increase understanding, or to develop designs for policy or program interventions. Risk reduction relies on sufficient knowledge accumulation and is built on a foundation of past observations. To this end, much energy has been expended to investigate whether there is empirical evidence for conflict risks under climate change (see, e.g., [7•, 35•, 84, 85•]. However, climate change may push natural and social systems to deviate from historical precedent. Under such circumstances, history may no longer be a reliable guide. Instead, opportunistic design thinking may be what is called for, where characterizing the future does more than simply improve system understanding—it aims to be a forum for experimentation and learning. Once the purpose of characterizing the future for decision support has been specified, analytical approaches should be selected that are fit for purpose [33]. Projections for conflict risk in the context of climate change based on statistical models may be suitable for risk reduction goals, but little can be learned from such models due to their lack of detail for contextual causal mechanisms.

Some argue that what is needed for security and conflict research in the context of climate change is a more nuanced research agenda, one that is responsive to the subtleties of societies with different histories and geographies [2•, 11]. In this vein, systems approaches may better enable deeper exploration of the interplay between socio-economic and climatic variables that contribute to conflict risk [1•, 85•]. These calls signify that even before conflict research can turn outward to provide decision support in the context of climate change to practitioners, much work remains within the community to increase knowledge accumulation, especially across quantitative (statistical) and qualitative (mechanistic) approaches [12, 84].

Some techniques for characterizing the future naturally lend themselves to learning, and the security and conflict research community could take these up as part of a system-theoretical research agenda. The rigorous exploratory method of CIB [54] has been presented as a concrete example of how security and conflict researchers could collate and systematize diverse quantitative and qualitative literatures across scales to explore their implications as a whole. CIB identifies scenarios that result from a self-consistent network of direct and indirect influences as well as their causal chains. This makes CIB especially appropriate for investigating alternative socio-economic conditions relevant for risks to human security or conflict.

Outside the security and conflict research community, the broader climate change research community has developed and is utilizing a two-part scenario framework for climate risk and policy analysis. The framework can be conceptualized as a menu of options for emission trajectories, or levels of climate change (RCPs), and alternative options for socio-economic conditions (SSPs). This framework follows from innovations in the SREX that conceptualize disaster risk as the co-occurrence of climatic and socio-economic conditions. This is consistent with the view that risks to human security are not determined solely by climate but are a function of climate change within a particular socio-economic context [21]. Security and conflict researchers can engage with the new RCP-SSP framework by combining RCPs with their own socio-economic scenarios (potentially derived with CIB), classifying their own socio-economic scenarios as consistent with particular SSPs (e.g., [82•]), or providing contextual detail for the implications of global RCP and SSP trends for risks to human security or conflict in particular places. The RCP-SSP framework aims to provide flexibility for a wide array of studies but also sufficient standardization to make studies comparable. Thus engagement with the RCP-SSP framework would support knowledge accumulation and integration for IPCC assessments. It may also serve as another vehicle for advancing knowledge in the field of security and conflict research in the context of climate change.

In summary, recent innovations in scenario analysis in the context of climate change offer multiple opportunities for knowledge accumulation around potential risks to human security and conflict. Some research opportunities are for resolving uncertainties internal to the field. The CIB method could be used to systematically investigate alternative hypotheses (whether qualitative or statistical) for the causal mechanisms of conflict and the roles played by climatic factors. Other opportunities are for quantifying the range of risk in the context of climate change. Using the RCP-SSP framework, investigators can systematically vary levels of climate change while holding socio-economic conditions constant (and vice versa). Results from such analyses will better distinguish how much risk to security and conflict is driven by changes in climate alone (alternatively, varying socio-economic conditions while holding the level of climate change constant distinguishes how much risk is attributable to socio-economic factors). Varying both the climatic (RCP) and non-climatic (SSP) factors will reveal how climate change could be an aggravating factor for security and conflict risks.

Compliance with Ethical Standards

Conflict of Interest The author declares that there is no conflict of interest.

Human and Animal Rights All reported studies/experiments with human or animal subjects performed by the author have been previously published and complied with all applicable ethical standards (including the Helsinki declaration and its amendments, institutional/national research committee standards, and international/national/institutional guidelines).

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