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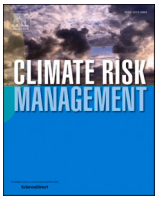

Climate-driven risks to peace over the 21st century

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ABSTRACT

Anthropogenic climate change is commonly characterized as a threat to human security. However, the extent to which and under what conditions climate impacts and responses may produce severe risks to peace have seen less systematically assessment to date. This essay provides a conceptual discussion of what risks to peace entail and how such risks might be considered severe, acknowledging that perceptions, values, and social scale must be grappled with in the identification of severity. Informed by available empirical research, the essay then explores the conditions under which climate-related risks could become severe during this century. Three illustrative scenarios based on different assumptions about climate-driven risks and risks related to social responses to climate change serve to illustrate how alternative warming and adaptation trajectories will have distinct implications for the prospect of future peace. The essay ends by reflecting on some implications for future research needs.

1. Introduction

Climate change is widely considered to be the defining challenge of our time (UN, 2008; WEF, 2021) with the potential for widespread risks to humans and nature (IPCC, 2022). Among its most devastating imaginable consequences are disintegration of social relations, breakdown of international order, and outbreak of conflicts and wars (Busby, 2018; CNA, 2007; Dyer, 2011; Welzer, 2017). Telling of the political significance of the issue, climate security today features regularly on the agenda of the United Nations Security Council, and although fundamental disagreements among members have prevented firm action there is evidence of increasing integration of climate-related risks in the Security Council's daily practices, procedures, and operations (Scartozzi, 2022).

This increased attention to climate change as a risk to security and peace is also reflected in recent assessments of the Intergovernmental Panel on Climate Change (IPCC). Since its conception in 1988, the IPCC has produced six major Assessment Reports on the state of scientific knowledge on climate change. The first four generations did not systematically consider climate-driven security risks (Gleditsch and Nordås, 2014), but the Fifth Assessment Report (AR5), published in 2014, included a chapter on 'Human Security' with a full section dedicated to climate change and armed conflict (Adger et al., 2014). Most recently, the Working Group II contribution to

Abbreviations: IPCC, Intergovernmental Panel on Climate Change; AR6, Sixth Assessment Report (of the IPCC); RKR, Representative Key Risk.

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the IPCC's Sixth Assessment Report (AR6),[1] released in 2022, not only assessed the evidence for observed impacts of climate on conflict but also considered how climate change could produce risks to peace in the future as part of the 'representative key risk' (RKR) assessment framework presented in Chapter 16 (O'Neill et al., 2022).

Despite a rapidly evolving empirical literature on climate-conflict connections (for overviews, see Koubi, 2019; von Uexkull and Buhaug, 2021), AR6 revealed a clear need for further consideration of how climate change could produce severe risks to peace in the future. Responding to that call, this essay presents an empirically grounded conceptual framework for climate-related risks to peace, which in turn informs an analysis of three illustrative scenarios of how climate and societal change jointly might affect risks to peace in the future. In doing so, the essay expands on the 'risks to peace' component of the RKR assessment by offering more nuanced definitions of central concepts while enabling deeper consideration of risks arising from social responses to climate change as well as those driven by climate change impacts.

2. What risk to peace entails

This section draws on the conceptual framework developed in AR6 as a basis for discussion and further refinement. Consistent with the representative key risk assessment, we first define what we mean by risk to peace before discussing how such risk could be considered severe. We also briefly reflect on the question of attribution of causality to climate change, which remains an intrinsic challenge when studying complex social outcomes such as armed conflict.

2.1. Definition of risk to peace

We begin with a definition of peace (and security) in a conventional, narrow sense as absence of organized lethal violence. It follows that risk to peace entails the potential for breakdown of peaceful social relations, materialized as overt violence at various social and spatial scales, from local (e.g., communal) violence to organized military conflict involving formal non-state or state-based armed actors within or across world regions.[2] This coincides with the notion of 'negative peace', which stands in contrast to 'positive peace', or absence of structural violence and social injustice more generally (Galtung, 1969). It also contrasts with the broader concept of human security, which exists when "the vital core of human lives is protected, and when people have the freedom and capacity to live with dignity" (Adger et al., 2014, p. 759).

Leading providers of statistics on armed conflict commonly operate with a minimum severity threshold for what is considered a relevant conflict, typically 25 or 1,000 annual battle-related deaths (Pettersson et al., 2021; Sarkees and Wayman, 2010). However, such quantitative thresholds may not be strictly relevant for defining what is a significant risk to peace because real and perceived consequences of a conflict depend not only on the magnitude of violence but also on characteristics of affected communities. Such consideration of the contextual features embedded in risk comes at the expense of not being able to rely on systematic data that would support statistical modeling of observed breakdown of peace. We return to this point when we address the definition of severity in the next section.

As a second distinction from common armed conflict datasets, our conceptualization of a breakdown of peace does not require that the nature of the violence must be explicitly political since the distinction between political and criminal violence can be blurry (for example sexual violence and other civilian targeting in the shadow of war). However, we emphasize the collective nature of violence to separate it from criminal activity and interpersonal violence, which we consider outside the scope of this analysis.

Finally, this definition engages with other representative key risks identified in AR6 (O'Neill et al., 2022). Climate-driven security risks always work indirectly via adverse societal and environmental changes, such that assessments of risk to, e.g., food security, living standards, and human mobility (Cattaneo et al., 2019; Dickerson et al., 2022) are inherently relevant for analyses of peace and security. Likewise, a breakdown of peace has high potential to negatively impact these broader dimensions of security (Bendavid et al., 2021; Buhaug and von Uexkull, 2021). Armed conflict is widely recognized as 'development in reverse' (Collier et al., 2003; Costalli et al., 2017) and constitutes a major driver of contemporary humanitarian crises and forced displacement (Anderson et al., 2021; Schutte et al., 2021; UNHCR, 2021), which again points to the relevance of this analysis for broader assessments of climate change risks (e.g., O'Neill et al., 2017).

2.2. Definition of severe risk to peace

The need to define severity stems from the desire to manage these risks – i.e., we need to understand how these conditions may emerge to develop strategies to moderate risks while acknowledging that this engages with values and perceptions of what is acceptable and desirable. The RKR assessment in AR6 considers risks to peace to be severe if they "result in at least 1,000 excess battle-related deaths in a country in a year" (O'Neill et al., 2022, p. 2464). The origin of this threshold can be traced to the definition of 'war' in major conflict datasets. As war constitutes the deadliest subset of armed conflict, it makes sense to use this classification to highlight especially severe outcomes.

[1] Unless specified otherwise, all mentions of AR6 in this article refer to the Working Group II contribution on *Impacts, Adaptation, and Vulnerability* (Pörtner et al., 2022).

[2] We use the term 'risk' in line with the IPCC's definition as "the potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems" (Möller et al., 2022, p. 2921).

Yet, the quantitative threshold is admittedly arbitrary, and it does not account for the fact that the loss of 1,000 lives would have very different societal and emotional impacts across populations that vary greatly in size and composition. The reference to battle-deaths statistics also fails to capture the full range of harmful social impacts from armed conflict. Recognizing this, AR6 considered climate-driven risk to peace to be severe also if the resulting violence has "cascading effects on other aspects of wellbeing and amplifies vulnerability to other RKRs", for example via widespread material destruction, compromised health and food security, mass displacement, ruined economic activity, and associated development impacts (O'Neill et al., 2022, p. 2464).

A more nuanced understanding of severity necessarily should be sensitive to the social scale of the risk as well as its potential for cascading impacts. Accordingly, we define a risk to peace to become severe when organized violence directly or indirectly results in widespread fatalities and fear of loss of life within a relevant population. Ultimately, in seeking to advance conceptual understanding of what constitutes a severe risk to peace, there is a need to strike a balance between simplicity and universal applicability on the one hand and flexibility and sensitivity to differences in values, perceptions, and social scale on the other. For that reason, we believe that a definition founded on a strict fatality threshold, even if normalized by the magnitude of population exposure, is suboptimal. Thus, although the revised definition provided here cannot easily be measured and is more open to subjective interpretation than the quantitative, country-level classification developed for AR6, it is scalable and explicitly accounts for the relative magnitude of risk.

2.3. Challenge of attribution

Before we move on to outline the scientific evidence base for how climatic hazards can constitute a risk to peace, a brief reflection on the challenge of detection and attribution is needed. There are two aspects to this challenge of relevance for our analysis. The first concerns the questions: Can we identify a clear climate effect, such that we can attribute some portion of the risk to climate change? How large and how consistent must a climate signal be in order to constitute a 'climate-driven risk'? Like many other social phenomena, armed conflict is always multicausal and there is broad scientific agreement that any influence of climate on conflict works indirectly and is highly context dependent (Gilmore, 2017; Koubi, 2019; von Uexkull and Buhaug, 2021). The complexity of nature-society relations means that it can be difficult to quantify and rank drivers of a given outcome such as armed conflict with high level of confidence. In the absence of better information, the distinction between a 'meaningful' effect and a trivial role often boils down to a question of statistical significance, even though p-values can be a poor indicator of substantive importance (Ward et al., 2010). Evaluating the relative importance of different drivers is even more difficult in less formal qualitative research. Although experts judge the average climate imprint on armed conflict to be modest at present, its relative contribution to the risk is expected to grow as the world warms (IPCC, 2022; Mach et al., 2019).

The second aspect of the attribution challenge relates to the characteristics of the climate system that is studied, where a main distinction can be made between short-term changes in weather and climatic conditions (inter- and intra-annual variations), including extreme events, and longer-term gradual changes in mean climatic conditions. Virtually all empirical research on climate-conflict connections explores consequences of short-term anomalies (e.g., interannual changes in temperature or variability in precipitation rates) as experienced in the historical record and not climate change per se. The extent to which results from such research can inform an analysis of security implications of climate change thus will depend partly on the extent to which studied variability patterns are

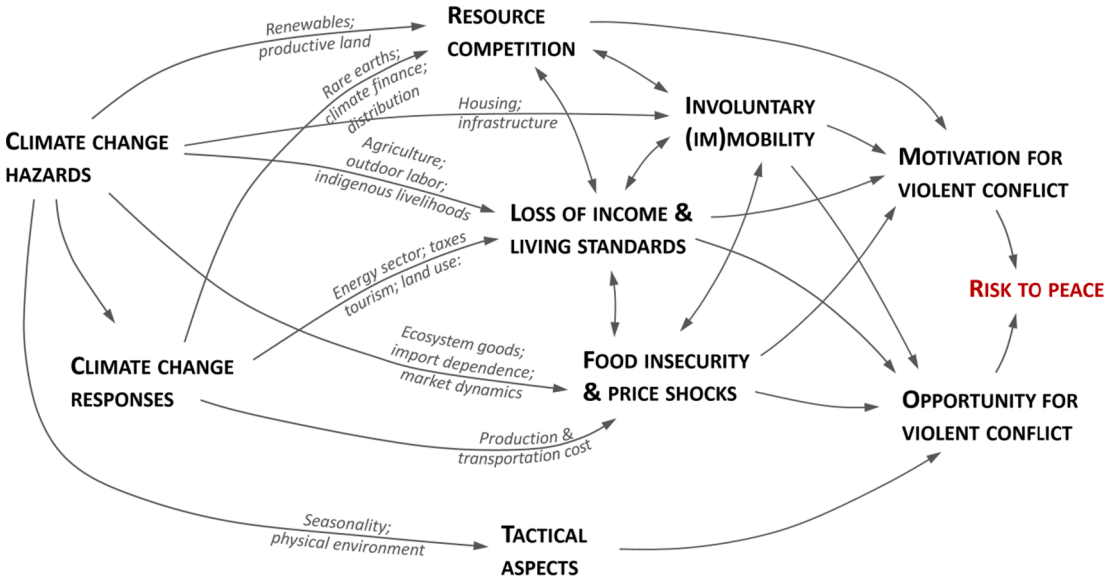

Fig. 1. Central pathways for climate-related risks to peace. The chart is deliberately parsimonious and does not feature important non-climatic factors that independently affect risks to peace, feedback effects from breakdown of peace, or social contexts that make these pathways more or less likely to materialize.

sensitive to climate change processes, partly on assumptions about the causal processes underlying the observed behavior, and partly on assumptions about whether relevant societies are likely to adapt to shifting average conditions. Owing to analytical complexity, few studies have tried to assess the statistical association between gradual changes in climatological conditions and shifting conflict behavior in the modern era (though see van Weezel, 2020). Even though recent years have seen significant progress in extreme weather and climate event attribution (Bellprat et al., 2019; Lahsen and Ribot, 2022; Otto et al., 2016), attributing some fraction of a given conflict outcome to climate change with confidence remains analytically challenging.

3. How climate (change) challenges peace

To motivate a discussion of how climate change might produce severe risks to peace in the future, we first outline five causal pathways commonly proposed in the empirical literature to describe existing climate-conflict links (Fig. 1). Given that there is limited scientific evidence of how gradual climate changes inform peace, we privilege pathways and mechanisms that can materialize on shorter time scales here, on the (reasonable) assumption that these dynamics will remain valid as average climate characteristics shift. Due to space constraints, we disregard studies focusing on the cooperation potential of environmental hazards (e.g., Bernauer and Böhmelt, 2020; Döring, 2020) as well as research on consequences of armed conflict for these intermediate conditions (e.g., Buhaug and von Uexkull, 2021). Readers interested in a more complete survey of the state of the art and its evolution should consult recent review articles on the topic (e.g., Gilmore, 2017; Koubi, 2019; Sharifi et al., 2020; von Uexkull and Buhaug, 2021).

3.1. Competition over renewable resources

The first pathway links climate change to violent conflicts over managed natural resources like water, arable land, and livestock. Such conflicts tend to be locally constrained and low-intensive and involve different land user groups. Agriculturally dependent rural societies in Sub-Saharan Africa are often discussed as potential sites of such conflicts (Benjaminsen et al., 2012; Bretthauer, 2015; Nordkvelle et al., 2017; van Weezel, 2019; von Uexkull and Pettersson, 2018). A common narrative relates drought to pushing pastoralists to encroach on the farmlands of sedentary communities in seek of forage, where the absence of well-functioning conflict management institutions lowers the barrier for using violence to settle arising disputes. Survey-based research also shows that drought exposure may increase individual acceptance for use of violence, although the effect typically is quite weak and conditional on other household characteristics (Linke et al., 2018; von Uexkull et al., 2020). The link between long-term drought and other gradual environmental changes and increased resource conflict is not universally supported by the empirical literature, which points to the complexity and context sensitivity of the role of climate in contributing to a breakdown of peace as well as likely bias in case selection (Adams et al., 2018; De Juan and Hänze, 2021; Hendrix and Salehyan, 2012; Seter et al., 2016).

Climate change may also lead to conflict over marine fisheries and territorial change or loss related to sea-level rise. Plausible mechanisms include migrating fish populations in response to ocean warming, leading to scarcity in some regions and abundance in others (Pinsky et al., 2018); contested maritime boundaries due to rising waters and artificial island-building; and loss of traditional farming and pastoral livelihoods that could increase the numbers of fishers and attendant fishing pressure (Mendenhall et al., 2020). Global climate phenomena like the El Niño Southern Oscillation may also drive year-to-year changes in fish abundance and thus related conflict behavior (Hendrix et al., 2022), which may become a more prevalent pattern under climate change (Cai et al., 2021).

3.2. Adverse economic and livelihood impacts

Another commonly proposed link between adverse climatic conditions and violent conflict works via the agricultural economy affecting both individual incomes and macroeconomic conditions. This can occur through shocks of disasters or longer chronic processes. At the macro level, major drought or other severe weather-related events can result in significant loss of revenues, cuts in welfare programs, and weakened state capacity (Ciccone, 2011; Koubi, 2017; Miguel and Satyanath, 2011), and expose government incompetence or unresponsiveness that increases public grievances, around which mass mobilization may occur. Incoming disaster relief funds also often are subject to appropriation or corruption by state and non-state actors, which serves as an additional source of frustration and anger (Leeson and Sobel, 2008; Yamamura, 2014). At the local level, extreme events can result in widespread loss of income and livelihood, which both lowers the opportunity cost of rebellion and increases inequality between communities, which may constitute a separate motivation for conflict (Buhaug et al., 2021; Ide et al., 2020; Maystadt and Ecker, 2014; von Uexkull et al., 2016). In general, there is more consistent evidence that this channel affects how conflicts evolve, e.g., by escalating or prolonging the conflict, than contributing to the initial outbreak of violence. In some contexts, severe disasters also can reduce levels of violence, at least temporarily, by undermining the ability of armed groups to mobilize resources (Kelman, 2011; Walch, 2018).

3.3. Food price shocks

A third, related consequence of climate variability and change with relevant implications for peace is shifting agricultural production dynamics and resulting market effects. Climate-induced loss of harvest can have profound short-term impacts on food prices. Rapid growth in food prices, in turn, is robustly associated with increased prevalence of urban social unrest, especially in food import-dependent countries in the Global South (Abbs, 2019; Bellemare, 2015; Hendrix and Haggard, 2015; Rudolfsen, 2020; Smith, 2014). Unlike other prominent climate-conflict pathways, which tend to highlight the local context, this mechanism may play out at regional to global scale. Global market response to export reduction in major food producers, compounded by adverse market dynamics (e.g.,

hoarding), can dramatically increase the cost of core food products for consumers far from the location of climate stress in the absence of expansive domestic food policies. An example of this is the impact of the 2010 drought and wildfires in Russia and several other major producers on growth in global cereal prices, which probably was a contributing factor to the timing of the Arab Spring uprisings (Costello et al., 2015; Soffiantini, 2020). However, although higher prices are bad for consumers and can trigger unrest in urban centers, they may benefit producers, suggesting that food price growth has distinct implications for risk to peace across social groups (Fjelde, 2015; McGuirk and Burke, 2020).

3.4. Involuntary (im)mobility

Individual decisions on mobility and immobility depend on a wide range of factors, and like armed conflict, attribution to climate change is challenging (IPCC, 2022). In the context of risk management, migration is most often a beneficial adaptive strategy (Black et al., 2011). Although the range of mobility types and variety of potential outcomes across receiving and sending communities make it difficult to draw generalizable conclusions (McLeman et al., 2021), involuntarily immobile persons as well as those displaced by extreme climate events are often especially susceptible to harm. Displaced persons without access to secure livelihoods may be vulnerable to radicalization and recruitment into armed groups (Schmid, 2016), and environmental migrants also may be more exposed to animosity and perceived conflict (Koubi et al., 2018). However, these same conditions of scarcity may weaken armed groups by undermining the economic resource bases on which they rely (Salehyan and Hendrix, 2014; Walch, 2018) and encourage individuals who could be vulnerable to recruitment to violence to migrate further away from conflict zones to avoid recruitment (Schaub and Auer, 2022). Climate and environmental change also can alter seasonal migration patterns in search of more favorable conditions for sustaining pastoral livelihoods, which could increase competition over fertile land and trigger farmer-herder conflicts in particular contexts (Benjaminsen and Ba, 2009; De Juan, 2015). However, sweeping claims that climate-induced migration leads to increased prevalence of armed conflict remains controversial and poorly supported by broad empirical evidence (Bosetti et al., 2020; Brzoska and Fröhlich, 2016; Freeman, 2017; Petrova, 2021).

3.5. Tactical aspects

Climate variability and extreme weather events also may alter the tactical or logistical opportunities for waging armed conflict. For example, temporal deviations from normal transition between the wet and dry season can affect the timing of battlefield intensity (Carter and Veale, 2013; Mack et al., 2021). Such dynamic is most relevant in areas shaped by distinct seasonality in climatic conditions. Similarly, seasonal fluctuations in vegetation may shape local conflict patterns. Cattle raiding, which is a distinct form of violent communal conflict in many African drylands, has been found to be sensitive to seasonal changes in environmental conditions, but also to anomalies from long-term seasonal averages (Adano et al., 2012; Ember et al., 2014). This points to how climatic conditions can inspire opportunistic behavior, but it remains unclear whether this pathway will produce greater overall risk to peace (as opposed to affecting the timing of fighting) in response to climate change.

3.6. Conditions increasing climate-driven risk to peace

An important insight from recent scholarship, also highlighted in AR6, is that the viability and strength of climate-conflict links across the five pathways outlined above are highly dependent on the local and national context. In general, factors that increase a society's vulnerability to climatic hazards also increase the climate contribution to the likelihood of armed conflict. Relevant factors include high dependence on agricultural livelihoods, fragile or inept governance institutions, exclusionary patterns of rule, unclear or insecure land tenure and lack of enforcing of property rights, and low levels or lack of inclusive development (Di Falco et al., 2020; Ide et al., 2020; von Uexkull et al., 2016). Incidentally, many of these factors also are adverse outcomes of armed conflict, such that political violence and climate impacts have the potential to trap societies in a vicious circle of adverse, mutually reinforcing processes (Buhaug and von Uexkull, 2021). Factors that make conflicts especially severe in terms of battlefield casualties often are different from the drivers of initial violence (Heger and Salehyan, 2007; Lacina, 2006). The extent to which climate change will increase severe risk to peace in the future thus is fundamentally dependent on whether and how societies develop and address non-climatic drivers of conflict, as well as how future outbreaks of violent conflict are managed by local institutions, states, and the international community (Hegre et al., 2016; Hoch et al., 2021; Witmer et al., 2017).

4. How responses to climate change challenge peace

While adverse impacts of climate change are traditionally understood as the key source of climate-related risks to peace, societal responses to climate change also could carry negative security implications. By responses, we here mean (i) efforts to moderate anticipated harm or exploit beneficial opportunities from climate change through various forms of adaptation, and (ii) efforts to cut carbon emissions and reduce the concentration of greenhouse gases in the atmosphere. To be clear, adaptation is generally considered beneficial for sustainable development and inclusive peace (Pelling and Garschagen, 2019; Regan and Kim, 2020; Tänzler et al., 2010), but tradeoffs between goals, uncompensated distributional effects, or unintended side effects could conceivably increase conflict potential under certain conditions (Gilmore and Buhaug, 2021; Ide, 2020). In subsequent paragraphs, we outline four complementary pathways that result in risks to peace. Notably, several of these pathways resemble, interact with, or exacerbate the climate-driven pathways (cf., Fig. 1).

4.1. Geopolitical implications of demand for new resources

With increasing awareness of the wide-ranging political economy implications of climate mitigation policy, the potential for new energy resources and precious metals to contribute to breakdown of peaceful relations has risen in prominence. There are two complementary storylines here. On the one hand, the growth in demand for wind and solar power, electric vehicles, high-capacity batteries, and other 'green' technology has resulted in a race for rare earth elements (REE) (Kalantzakos, 2020). Several of these metals, such as cobalt, are geographically concentrated in countries with weak governance structures and high levels of corruption, which raises concerns about implications for peace and security (Månberger and Johansson, 2019). Aside from potential military contestation over control of mining fields, REEs also could stimulate resource curse dynamics that have known links to violent conflict (Humphreys, 2005; Månsson, 2015; Ross, 2015). On the other hand, a rapid decline in global demand for carbon-based energy consistent with net-zero emission goals might result in dramatic loss of revenue among major oil and gas exporters. Unless these economies succeed in finding new sources of income, the result would be increased social discontent and high probability of political instability as citizens experience a widening gap between desired and realized standards of living (Gilmore and Buhaug, 2021; Van de Graaf and Verbruggen, 2015).

4.2. Distributional changes from mitigation and adaptation actions and finance

A second security challenge concerns future reallocation of productive land to mitigation projects, such as production of hydropower or bioenergy with carbon capture and storage (BECCS). Leading climate scenarios based on BECCS absorb new land of an area up to three times the size of India (Cavanagh, 2021; Hickel, 2021), with unavoidable impacts on local resource access and land use. Numerous examples of violent resistance to the marginalization or outright eviction of populations from afforestation and green conservation programs may be an antecedent of things to come if these projects progress to the scale projected for deep decarbonization pathways without commensurate considerations of social and environmental safeguards and acknowledgement of the inherent rights of Indigenous Peoples (Alusiola et al., 2021; Bergius et al., 2020; Beymer-Farris and Bassett, 2012; Cavanagh and Benjaminsen, 2014; Duffy, 2016; Schmid, 2022; Sovacool, 2018). Policies designed to curb fossil fuel use, such as cuts in consumer subsidies for cooking and fuel taxes, have also been met with collective and occasionally violent resistance in locales as diverse as France (Stephens, 2019), Nigeria (Houeland, 2020), and Ecuador (Díaz Pabón and Palacio Ludeña, 2021). A related concern is that financial flows for adaptation and mitigation programs might be misused to entrench the interests of elites, preserve extant sociopolitical cleavages, or support other agendas incompatible with sustainable development. The power asymmetry between relevant actors means that any ensuing conflicts would likely be modest in battlefield intensity but impacts still could be severe for affected local communities.

4.3. Maladaptation, lack of coordination, and poor implementation

Third, projects could be maladaptive such that they fail to reduce risks, reduce one type of risk but accentuate another risk, or reduce risk for one population group on expense of another, and as such could constitute a source of new conflict. For example, infrastructure projects that address water scarcity in one location may result in worsening climate impacts elsewhere; expanded use of irrigation to ensure agricultural growth despite drying may diminish water available for human consumption; and coal-replacing hydropower plants may systematically alter river flow with adverse ecological and socioeconomic impacts on dependent downstream systems (Dabelko et al., 2013; IPCC, 2022; Krampe et al., 2021). Additionally, there is evidence that national adaptation planning often fails to consider social equity considerations (Smucker et al., 2015). Unequal access to the benefits of such projects may worsen development conditions and accentuate grievances related to inequality and lack of secure livelihood, and thereby engender risks to peace similarly to how discriminatory climate impacts could motivate violent conflict.

4.4. Insufficient action to limits the adverse impacts of climate

A final climate-related risk to peace considered here stems from taking insufficient action. As public experiences with climate impacts grow (cf. Fig. 1), individuals may become less tolerant to the commensurate risks. Increasing perception of a government's inability (or unwillingness) to protect its citizens from climate-driven harm may foster social unrest, especially if the social environment is conducive to broad mobilization and collective action (Ide et al., 2020; see also Olson, 1965; Tilly, 1978). This dynamic also might play out at the international scene, where vulnerable societies in the Global South, perhaps supported by progressive green economies, become increasingly impatient with sluggish mitigation rates in much of the industrialized world. A related scenario is the notion of military eco-humanitarian interventions in protection of nature (Eckersley, 2007). Such risks to peace are perhaps not likely to become severe (i.e., armed conflict with widespread loss of lives is unlikely) due to the vast imbalance in military capabilities between actors, but it could alter the international political environment in other ways.

5. Illustrative scenarios of severe climate-driven risks to peace

The RKR assessment in AR6 judged that climate change does not presently constitute a severe risk to peace at the global level (O'Neill et al., 2022). However, depending on how the climate and societies change over the course of this century, climate-driven risks may become severe as a result of (i) intensifying climate-related impacts on sectors, processes, and systems, as well as compounding and cascading impacts, that in turn increase the probability of major armed conflict, and (ii) adverse side-effects of societal responses

to climate change as described in previous sections. It was, further, assessed that the likelihood of severe risk will continue to be shaped primarily by non-climatic (i.e., vulnerability) factors in the near term, but higher levels of warming will have increasing bearing on risk outcomes (O'Neill et al., 2022, p. 2465).

In the following, we present three stylized scenarios to explore different implications for how climate change might affect future peace and security (Fig. 2), building on the RKR assessment and the extensions offered above. This qualitative scenario analysis is informed by the best understanding of the authors on how climate and conflict are connected today (drawing on the post-World War II record), along with distinct assumptions about how societies will respond to climate change over the 21st century. We do not evaluate the relative likelihoods of individual pathways or which scenario entails greater overall risk to peace but rather use these scenarios to illustrate pathways to conflict that are tied to specific societal futures. Moreover, although the three scenarios bear resemblance to specific Shared Socioeconomic Pathways (SSPs) (O'Neill et al., 2014; Riahi et al., 2017), our scenarios are decidedly simpler than the SSP framework in that we do not make assumptions about of how societies develop beyond their adaptive and mitigation response (i.e., we assume that underlying drivers of socioeconomic development and demographic change are similar across the scenarios).

Scenario A: Unmitigated climate change and continuation of current adaptation trends.

The first scenario we consider assumes mounting climate change impacts and associated risks. It is defined by continued reliance on fossil fuels for energy production and economic growth, where transition to renewables is driven only by market forces and technological innovation and not induced through climate policy (beyond those currently in place, which are assumed to continue). Adaptation to climate change continues at historical rates, rather than at a rate that would be commensurate with the growing risks with hard limits being reached. This would result in a world that is around 2.8 °C warmer in 2100 than in the pre-industrial era (UNEP, 2022) and where countries increasingly fail to manage accelerating climate change impacts and the associated losses and damages.

In this world, more extreme and unpredictable weather constitutes a growing challenge for climate-sensitive economies and livelihoods, as current adaptation trends have failed to obviate these challenges in the present. Agriculture-dependent communities in Sub-Saharan Africa, South Asia, and Central America, and Indigenous Peoples in small islands and the Arctic are increasingly facing adaptation limits shaped by permanently altered environments, insufficient adaptation finance, and slow implementation of new technology. The result is compromised household economic security and increasing exposure to hazard events that would increase incentives for migration. For example, if resources cannot be marshalled to enhance local adaptive capacity in rural areas, larger number of households and communities may move to urban centers. With insufficient resources in the urban centers, this change in population could accentuate existing social challenges and expose the migrants to new risks (Bosetti et al., 2020; Spilker et al., 2020).

Increasing income inequality between social groups at different levels of vulnerability and rising socioeconomic marginalization in urban as well as rural regions imply lowered opportunity cost of dissent. In areas where economic hardship overlaps with political exclusion, climate impacts would contribute to higher probability of radicalization and violent extremism (Cederman et al., 2013; Stewart, 2008). Increasing environmental degradation and more volatile agricultural yields also could contribute to armed conflict through accentuated incentives for capturing dwindling fertile land and resources (McGuirk and Burke, 2020), and rising food prices that serve as an important mobilization base for social unrest (Hendrix and Haggard, 2015).

Growing popular resentment with government inaction is another significant risk to peace in this scenario that applies as much to wealthy societies as to vulnerability hotspots, especially through uncompensated losses and damages. Likewise, the industrialized

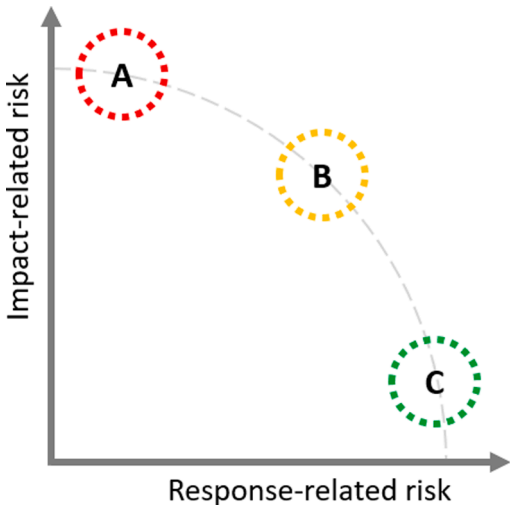

Fig. 2. Stylistic climate and societal change scenarios with implications for risk to peace. Scenario A entails a future world with low mitigation and low adaptation; Scenario B denotes low mitigation but high adaptation; Scenario C implies high mitigation and high adaptation. For simplicity, all scenarios are placed at the same distance from the origin, which represents a theoretical world without climate change, although in reality overall climate-driven conflict potential probably would vary between these worlds.

world's collective lack of will to invest in mitigation measures or provide adaptation finance might generate powerful popular resentment within the Global South, as well as among citizens in high-income countries that support more stringent climate policy. A major military confrontation between key emitters and victims of climate change would certainly constitute a severe risk to peace at regional to global scale, although such tensions would more conceivably inspire waves of 'eco-terrorism' within the developed world (Spadaro, 2020) or challenge the functioning of international trade agreements as well as the UN system.

Scenario A also could lead to new conflict constellations in the Arctic, due to increased economic activity facilitated by the melting of the ice cap and related resource extraction and rising security concerns driven by military build-up in the region (Markowitz, 2020; Tamnes and Offerdal, 2016). Sea-level risk could similarly contribute to international disputes over attempts to redefine maritime zones in response to submerging low-lying coastlines, islands, and atolls, especially in strategically important regions, such as Spratly Islands in the South China Sea.

There is, however, also evidence that would suggest that a low mitigation, low adaptation scenario – with continuing economic growth and increasing trade interdependence – actually would be characterized by fewer wars, at least between states (Gartzke, 2012). This conjecture assumes that prevailing relationships between interstate trade and conflict from the late-19th and 20th centuries will continue to operate in a future characterized by rapid climate change; since 2007 the global trend has been toward deglobalization and lessened trade integration (Irwin, 2022).

Scenario B: Unmitigated climate change but high levels of adaptation.

The second scenario is reactive to climate change impacts and risks. In contrast to the first scenario, all countries in Scenario B respond to increasing climate change-driven hazards by investing in adaptation at near maximum capacity (i.e., there is considerable political support for adaptation, and measures are constrained primarily by availability of skills and resources in a location), although economic development continues to rely heavily on fossil energy sources. End-of-century global mean surface temperature is around 2.8 °C above pre-industrial levels, but material and social impacts of climate change hazards over the course of this century are much smaller than in Scenario A for most people due to higher average resilience in both high- and low-income societies.

One climate-related pathway to conflict that remains relevant in this scenario is loss of income and livelihoods in climate-sensitive sectors. Although most societies will be much better equipped to cope with the growth in hazards than they are in the first scenario, in regions where ecological and socioeconomic systems are already close to hard adaptation limits (typically in hot and semi-arid regions and in locations threatened by sea-level rise or freshwater depletion), residual risk may be substantial, including the prospect of violent conflict over dwindling resources between communities or against governments over failure to address the root of the problem. Since the ability (and viability) to cope and adapt in situ is very unevenly distributed within and across societies, a plausible outcome in this world, compared to Scenario A and C, is a much wider gap between the winners and losers of adaptation (King and Harrington, 2018; Sovacool et al., 2015). Yet, Scenario B also would be consistent with an alternative storyline where rich countries not only maximize own adaptation but also offer comprehensive adaptation finance to support the most vulnerable countries.

The high and increasing cost of sustained adaptation as warming continues unmitigated is another potential source of growing discontent in Scenario B. In low-income countries, resentment could increasingly be targeting the Global North but in high-income countries, governments might be challenged by segments of their citizens with demands for policy change. Given that the median voter remains opposed to expanded climate policy (an underlying assumption of the scenario), this could lead to growing polarization of the political landscape, decline in social and political trust, and increasing rates of violent social disorder between supporters and opponents of climate mitigation (cf. Citrin and Stoker, 2018; Stoddard et al., 2021).

As in Scenario A, increased military and economic activities associated with the melting of the Arctic would be expected to raise the likelihood of armed confrontations between major powers with stakes in the region.

Scenario C: High levels of mitigation and adaptation.

The third scenario proactively seeks to minimize climate change impacts and related risks. Here, countries invest what is required to achieve the most ambitious target of the Paris Agreement, to limit global warming to 1.5 °C above pre-industrial levels by 2100. This entails rapid phasing out of carbon-based sources of energy, dismantling of fossil fuel subsidies, and significant new investments in green technology and infrastructure (IPCC, 2018). To further minimize climate-driven risk, countries dedicate high levels of funding for adaptation to hazards that cannot be avoided. This scenario will see the lowest prevalence of climate-driven risk to peace (cf. Fig. 2), but possibly on the expense of increased risk related to the comprehensive and (perceived) costly societal responses to climate change.

We focus on three plausible climate response-related pathways to severe risks under this scenario. The first concerns adverse economic impacts and resulting weakened state capacity as a result of rapid decarbonization. For fossil-fuel exporting countries, a rapid global decline in demand for oil and gas means production capacity drops quickly and comprehensively. As the resource rents from these exports are the foundation of domestic stability in many resource-exporting countries (e.g., by sponsoring patronage networks and repressive capacities (Wright et al., 2015)), the global energy transition implies fewer resources to invest in either repressive or accommodative responses to social unrest. Current evidence of economic diversification among fossil-fuel exporters is weak (Hendrix, 2019; Ross, 2019), suggesting that declining export revenues will occur against a backdrop of growing economic hardship, increasing the probability of armed conflict and state collapse (Lucas and Richter, 2016; Smith, 2017).

A knock-on effect of increasing fossil fuel taxes and lasting lack of alternatives to jet airliners for long-distance travel could be a dramatic decline in income in many major tourism-dependent economies as holiday travel patterns will shift to destinations

compatible with green tourism. This effect would be especially pronounced in exotic locations not reachable by ground transportation (e.g., small islands in the Caribbean, Indian Ocean, and the Pacific). Statistics from the World Tourism Organization reveal that the tourism industry typically contributes 20–70 % to the gross domestic product in these countries, which indicates the magnitude of the potential income shock. Likely implications of such economic losses include large-scale out-migration and violent local resistance against falling living standards, although the potential for severe conflict is judged to be considerably smaller than among fossil fuel-dependent societies.

Another pathway to conflict shown in Fig. 1 relates to competition over highly valuable rare earth elements and minerals, which will be increasingly in demand for high-tech industry and renewable energy production underpinning green transition (Deetman et al., 2018; van Exter et al., 2018). Although it is far from inevitable that such competition would result in violent conflict, at least three distinct conflict typologies can be envisioned as part of this dynamic: (i) violent local resistance against external mining companies over inequitable distribution of economic benefits and highly concentrated environmental costs of these extractive industries (Conde, 2017; Peša and Ross, 2021); (ii) growing separatist aspirations in resource-rich provinces¸ particularly when these resources are concentrated in areas dominated by historically marginalized ethnic or religious groups (Morelli and Rohner, 2015; Ross, 2004); and (iii) increasing foreign (major power) intervention – financially but potentially also militarily – to secure access to the critically important minerals (Andersson et al., 2018; Salehyan, 2010).

Lastly, household economic impacts of mitigation policies may incentivize violent protest and disorder also in currently peaceful middle- and high-income regions. Consumers in these countries may see fuel prices increase rapidly, with larger proportional effects for those who remain reliant on fuels for electricity, heating, mobility, and livelihood. Increasing transportation costs also translate into higher food and commodity prices for imported goods. Even though the median voter in this scenario is assumed to accept the costs of climate change abatement to minimize climatic hazards, increasingly disenfranchised segments of the populations might contribute to broad losses in legitimacy across the political spectrum. Bereft of popular legitimacy, political institutions could be the target of violent mobilization that draw on existing politically salient social cleavages, similarly to how the International Monetary Fund and various austerity programs have motivated repeated episodes of popular resistance around the world in recent decades (Auvinen, 1996; Walton and Ragin, 1990).

6. Imagining the unimaginable

Informed by relevant literature assessed in AR6, the illustrative scenarios discussed in the previous section indicate that climate-related risks to peace are mostly relevant at (sub)national levels, where non-climatic factors are expected to remain the primary determinants of violent conflict into the long-term future (IPCC, 2022). However, as the effects of human-induced climate change are projected to be unprecedented, the changes may provoke yet unknown risks to geopolitics that cannot be explored within the existing record (Busby, 2018). Of specific concern is that climate change will pose serious risks to interstate relationships and cause disruptions to world order (McDonald, 2013). In the following, we briefly consider some of these more speculative risks, drawing upon the low likelihood, high impact (LLHI) storyline approach advanced in the AR6 WGI Report, which focuses on the processes that may be less well understood and difficult to constrain but if they were to occur, would entail large and long-term risks (IPCC, 2021).

Our first set of concerns relate to the prospect that climate impacts and risks increasingly overwhelm the institutional capacity and functioning of governments and supranational organizations alike. The potential for climate risks to destabilize conditions and challenge the territorial integrity of states would typically be highest in regions with existing tensions and high military capacity. Relevant examples proposed in the literature include large-scale, unmanageable international migration, which could “spark war by heightening competition over scarce resources and by upsetting the cultural or ethnic order within a country or region” (Podesta and Ogden, 2007, p. 117), and water shortages in transboundary river systems, which “could combine with other antagonisms to trigger armed conflict, possibly entailing the use of nuclear weapons” (Klare, 2020, p. 120). A related, more extreme version of this logic sees a potential for climate change to produce existential risks to humankind through catastrophic cascading impacts and feedback loops (Huggel et al., 2022; Kemp et al., 2022).

A second set of severe risks to the international order could stem from concerns that implemented actions to mitigate climate change are insufficient to avoid damages and that solar radiation management (SRM) will be necessary to manage these risks. One of the most plausible SRM options is stratospheric aerosol injection, which could be applied to produce temporary cooling (National Academies of Sciences, Engineering, and Medicine, 2021; Versen et al., 2022). However, in the absence of coordinated governance mechanisms, capable states might opt for unilateral deployment, which could be perceived as hostile regardless of the intent. Additionally, there are many unknowns related to SRM, including the potential for unequal distribution of benefits and damages (Tang and Kemp, 2021) that could trigger hard-to-contain military retaliation.

We conclude this section by also stressing that the empirical evidence strongly supports environmental cooperation and the management of transboundary resources that contains political tensions (e.g., Bernauer and Böhmelt, 2020). Dramatic and far-reaching changes in the relationships between states are not without precedent (most recently evidenced in the Russian invasion of Ukraine); however, the drivers of these breakdowns have been non-climatic and thus, these scenarios cannot be assigned likelihoods drawn from empirical evidence. Additionally, while such changes are often related to or generated through nationalism and violence, peaceful international relations are commonly shaped through trade or other arrangements that are cooperative and self-reinforcing. Thus, elaborating the scenarios that would generate severe risks also allows a test of the alternative framings of cooperation and governance.

7. Concluding remarks

Considering the complex, indirect, and highly context-sensitive nature of climate-security interactions, deep uncertainties exist regarding the probability and magnitude of plausible future insecurity outcomes of climate change. Recent reviews and assessments have proposed a number of important scientific advances that could reduce some of those uncertainties (e.g., Buhaug and von Uexkull, 2021; Mach et al., 2020). Here, we highlight three knowledge gaps of particular relevance for climate-related risk to peace in the longer term that have received limited scholarly attention to date.

First, scholars should invest more in seeking to understand how climate change and knock-on processes related to impacts and responses affect interstate dynamics. To date, the literature linking climate to intrastate conflict vastly exceeds that concerned with interstate relations. Beyond transboundary rivers, we know little about how changes to co-managed resources like fisheries and aquifers will affect future patterns of conflict and cooperation between states. While there are posited mechanisms (e.g., Mendenhall et al., 2020; Petersen-Perlman et al., 2017; Schmidt et al., 2021), there are few observational studies that could inform forecasting or scenario development. Also, as suggested in the brief scenario analysis there is significant potential for future tension between countries that manage to cut emissions in order to meet the Paris Agreement and those that do not, as well as between countries deeply invested in climate-forcing (hydrocarbons, ranching) and climate-vulnerable (coastal property, fisheries) assets and economic activities (Colgan et al., 2021). Although empirical evidence that such disputes could escalate to the use of lethal military force fortunately is lacking, there are other scientific tools that could be used and analogous historical cases that could provide insights to explore future climate-driven risks to international peace and stability (Mach et al., 2020).

Second, scholars should invest more in understanding the second- and third-order effects of climate change for security outcomes that arise from adaptation and mitigation efforts, as well as ways to manage such complex risks. Examples include (i) decarbonization and its effects for fossil fuel-exporting countries, notably in the Middle East; (ii) the critical mineral boom and its effects on security outcomes in resource-rich countries; (iii) the conditions under which climate-related mobility and immobility affect risk and shape host-migrant interactions; and (iv) potential retrenchment of social spending and subsidy programs due to costly climate policy. In doing so, scholars will need to confront issues of endogeneity and simultaneity – i.e., that decisions related to, e.g., economic transformation or migration influence but also are influenced by prevailing security contexts – that can often be ignored in empirical studies focusing on the effects of weather-related climate shocks.

A third priority for future research in this field concerns cross-risk interactions. Climate-related hazards do not inform the likelihood or severity of armed conflict directly. Rather, this could be adverse knock-on effect of climate-driven loss of income and livelihoods, weakened state capacity and rule and law, or unsustainable, inefficient, or inequitable political responses that in turn accentuate prevalent social grievances and lower collective incentives for use of violence. There is a clear need for better integration of research across these intermediate outcomes with analyses of conflict and instability that also account for important feedback loops from conflict to economic and food security and human mobility. Hopefully, IPCC analyses of security implications of climate change in the coming seventh assessment cycle will have a much richer scientific literature to draw on that both considers relevant international (geopolitical and other) dimensions of security, adverse security effects originating in societal responses to climate change, and integrated studies that combine key intermediate impacts with conflict outcomes and further incorporate the latter's influence on subsequent vulnerability to climate change.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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