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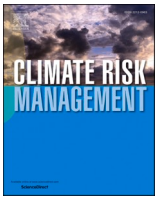

Complex climate change risk and emerging directions for vulnerability research in Africa

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ABSTRACT

This article explains the assessment and conceptual framing of the Vulnerability Synthesis in the Africa chapter of the Intergovernmental Panel on Climate Change's (IPCC) 6th Assessment Report (AR6), situating the synthesis within emerging understandings of complex climate change risk, intersectionality and multi-dimensional vulnerability. It highlights how reducing vulnerability holds the greatest potential gains for reducing near-term climate risk in Africa. It elaborates how important dimensions of vulnerability, such as inequalities of gender, migrant status or level of income, compound with each other to affect risk. Our review of current vulnerability scholarship reveals severe limitations for climate risk management that are rooted in a lack of attention to interacting social drivers and their effects on risk, as well as an orientation toward vulnerability analyses at coarse social and spatial levels. These scales do not match well with the localised nature of vulnerability nor the impacts of climate change. There is also limited research on the intersectional differentiation of vulnerabilities, which is essential to understanding the heterogeneous nature of vulnerable groups and their agency, particularly concerning navigating or contesting unequal power relations. Reflecting on these dimensions in the Vulnerability Synthesis, we identify how research can provide a deeper understanding of the interactions among multiple drivers of vulnerability and why this matters for adaptation in Africa. Key to this understanding will be to show how responses to climate change affect important dimensions of vulnerability and with what overall risk outcomes. Doing so will advance intersectional analysis within place-based vulnerability assessments across Africa and better inform the design of interventions targeting those dimensions and scales of vulnerability that have the greatest proportional effect on risk reduction. These will contribute informed safeguards against maladaptation as well as provide concrete directions for planning for more inclusive climate-resilient development.

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1. Introduction

Vulnerability is the propensity or predisposition to be adversely affected (IPCC, 2022). In the context of climate change, vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. Such factors include dimensions of exposure, such as presence of people, livelihoods, species or ecosystems, infrastructure, or economic, social, and cultural assets in places and settings that could be adversely affected. Vulnerability is also determined by capacity to adapt to climate change and its effects to moderate harm (Brooks et al. 2005). Vulnerability is unevenly distributed on all scales, as sensitivity to the impacts of climate change vary. These dimensions of vulnerability affect each other and contribute to

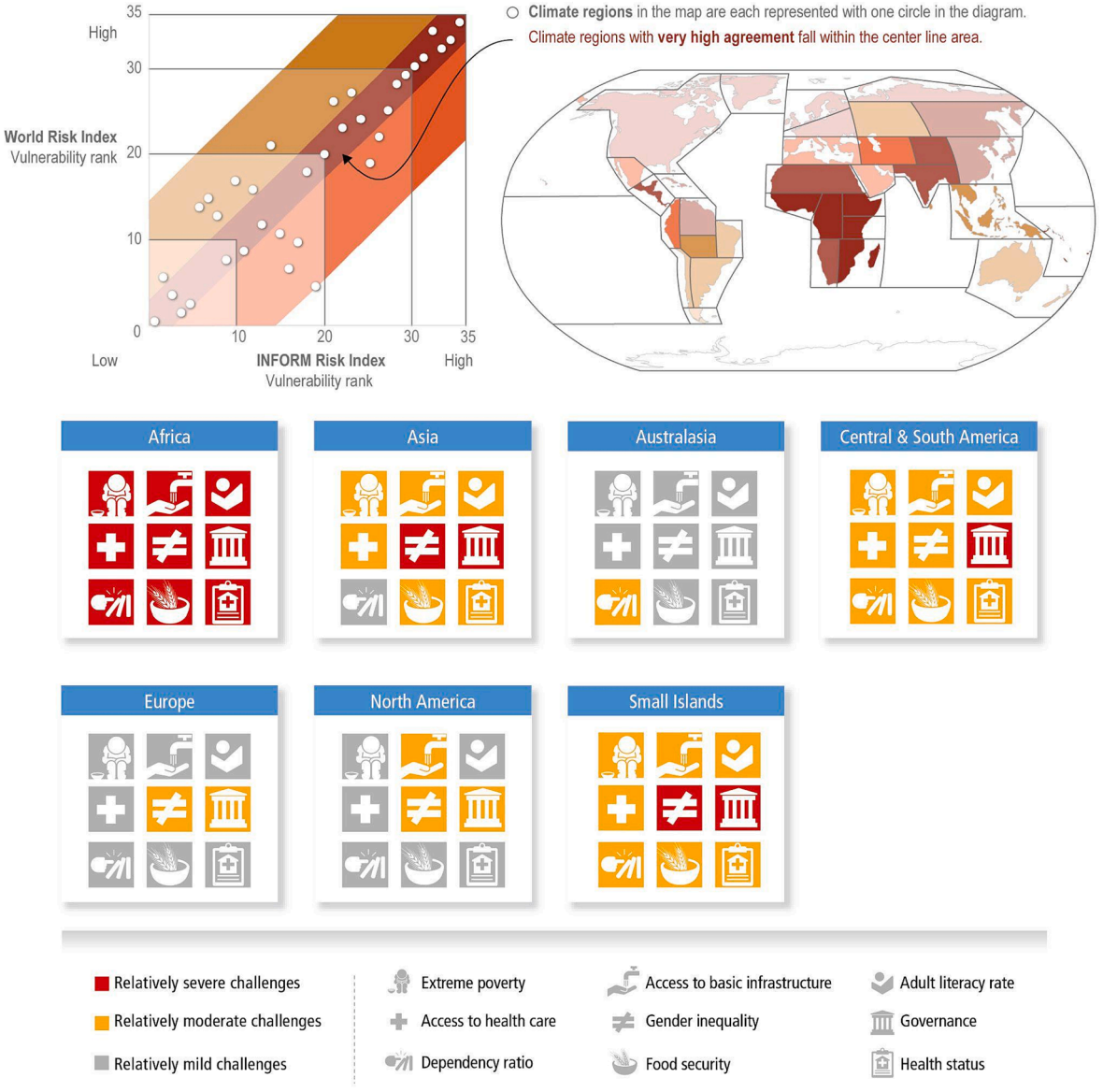

Fig. 1. Global assessment of absolute and relative vulnerability to climate change. Top: Aggregated vulnerability map at the scale of climate regions based on the averaged ranking of the INFORM Index's vulnerability component and the averaged ranking of the vulnerability component of the WorldRiskIndex assessed by Chapter 8 in AR6 WGII (used with permission, Birkmann et al., 2022). Darker map colours show regions of higher vulnerability with strong consensus across indicators that Africa stands out as the most vulnerable region globally. The diagram shows how the 35 climate regions are ranked by each index and also serves as a legend for the map top right. Bottom: The figure highlights the relative vulnerability of Africa compared with other regions of the world through showing selected aspects of human vulnerability, such as extreme poverty and inequality, and access to healthcare and basic infrastructure as regional averages assessed by Chapter 8 in AR6 WGII (used with permission (Birkmann et al., 2022)). These vulnerability aspects are a selection of indicators from the indicator systems used for the global vulnerability map (Birkmann et al., 2022).

climate change risk, making understanding of vulnerability a critical dimension of climate risk management (O'Neill et al., 2022; Simpson et al. 2023).

This Perspective presents an elaboration and critical reflection on the vulnerability synthesis of the Africa chapter of the Intergovernmental Panel on Climate Change's (IPCC) 6th Assessment Report (AR6). The literature on climate impacts, vulnerability and adaptation to climate change produced between 2014 and 2021 was assessed by a team of close to 100 authors during AR6 (Trisos et al., 2022). A synthesis of the final draft of the climate change assessment was conducted drawing on insights on vulnerability across the sectoral chapters on ecosystems, water, food systems, human settlements and infrastructure, health, economy, poverty and livelihoods, heritage and indigenous and local knowledge systems. The evidence on vulnerability was then assessed by considering the factors contributing to the progression of vulnerability to climate change across African contexts using categories of socio-economic processes, resource access and livelihoods, and intersectional and compounding dimensions of vulnerability. In the process, the assessment identified knowledge gaps in Africa and uneven research resources.

The Africa chapter highlights how vulnerability to climate change in Africa is produced through multi-dimensional and intersecting socioeconomic, political and environmental processes which contribute to social patterns of vulnerability and ultimately climate change risk (Trisos et al., 2022). The report showed that 95 % of African cropland is rainfed while African economies are disproportionately dependent on climate-exposed sectors, with 55–62 % of the sub-Saharan workforce employed in agriculture (Trisos et al., 2022) and high levels of sensitivity to extreme events as reflected in reductions in crop yield qualities and quantities and wider impacts on smallholder livelihoods (Ayanlade et al., 2022). Further, poor and female-headed households in rural Africa face greater livelihood risks from climate hazards (Dzvimbo et al., 2022), while in urban areas, growing informal settlements without basic services increase the vulnerability of large populations to climate hazards, especially women, children and the elderly (Pelling et al., 2021; Trisos et al., 2022). Vulnerability is therefore both a major contributor to climate change risk in Africa and reducing vulnerability is one of the most urgent and effective means for reducing risk in Africa.

Africa is assessed with "high confidence" by the IPCC to be the region most vulnerable to climate change globally due to compound challenges of high levels of poverty, a significant number of people without access to basic services, such as water and sanitation, and wealth and gender inequalities, as well as governance challenges (Birkmann et al., 2022). Fig. 1 demonstrates agreement between two global vulnerability indices when ranking climate regions according to their vulnerability. Areas of high human vulnerability are characterised by larger transboundary regional clusters and affected by factors such as extreme poverty and inequality, and access to healthcare and basic infrastructure.

Yet assessment of vulnerability is highly challenging in Africa. While Africa is covered by the second highest number of adaptation and vulnerability studies of all world regions, the geographic distribution of these studies within the region is highly uneven (Berrang-Ford et al. 2021, de Sherbinin et al. 2019). Uneven geographic coverage of vulnerability assessments may reflect economic characteristics such as countries' contribution to the region's agricultural output, rather than the distribution of potentially vulnerable groups, with a majority of studies conducted in Western and Southern Africa (Williams et al. 2018). Although there is a tendency to focus more on vulnerable groups such as smallholder farmers, there is still limited engagement with local perspectives and knowledge (Williams et al. 2018). And while frameworks have become less hazard-centric, involving greater attention to social aspects (Hagenlocher et al. 2019), there are still deficits regarding the conceptualization of vulnerability and, especially, the empirical operationalization and implementation of this in vulnerability assessments (Williams et al. 2018).

Integrating multiple dimensions of vulnerability involves attention to the complexity and the differential effects of each dimension on overall vulnerability. Innovation to the IPCC risk framework during the AR6 process now includes the idea of responses (both greenhouse gas mitigation and adaptation) as a determinant of risk (Andrews et al., 2023; Simpson et al., 2021; Ara Begum et al., 2022). The new IPCC risk framework also now gives much greater attention to the aggregating, compounding or cascading interactions of multiple drivers of vulnerability (Simpson et al., 2021). This innovation is particularly important to advance our understanding of vulnerability and overall risk as common understanding of vulnerability includes the idea of adaptive capacity as a dimension of response and important for risk reduction, yet there has been a failure to integrate responses in climate risk assessment and management. While exposure is commonly considered a determinant of vulnerability (Adger et al., 2018), prior to this new risk framework it has been ambiguous within the IPCC risk assessment as to the specific nature of interaction between multiple exposures and multiple vulnerabilities particularly when the two concepts are disaggregated (Simpson et al., 2021). It is also important because inappropriate responses can increase vulnerability and lead to maladaptation (Eriksen et al., 2021; Schipper, 2022). Finally, in contrast to its previously limited scope within the agenda of Working Group II, this innovation now extends vulnerability to all three Working Groups of the IPCC by including the potential effects of GHG mitigation responses on vulnerability, independent of a proximate climate hazard (Andrews et al., 2023; Simpson et al., 2021). The new risk framework makes explicit how each dimension of vulnerability affects and is affected by other determinants of climate change risk (including exposure, hazards, and responses to climate change) and therefore which dimensions of vulnerability should be targeted for the most effective and feasible climate risk assessment and management.

Vulnerability is therefore the outcome of complex, multi-layered and multidimensional processes that span a range of spatial, social, and temporal scales. As a determinant of climate change risk, generating knowledge on each of these scales and in these dimensions is essential to effectively assess vulnerability and envision pathways of vulnerability reduction. Furthermore, it is increasingly recognized that the dynamic social patterns of vulnerability resulting from these processes transcend the contours of individual vulnerable groups as defined by specific markers of social status, identity, livelihood orientation or location. Climate risk assessments to date have not systematically integrated the idea of intersectionality with emerging understanding of the multiple determinants of complex climate change risk. In the sections that follow, we outline the key conceptual advance of the IPCC risk framework in relation to vulnerability, highlight interactions among key drivers of vulnerability in Africa assessed through synthesis of the Africa chapter of the IPCC's AR6 (Trisos et al., 2022), and sketch future research directions for Africa concerning its implementation.

2. Vulnerability and climate change risk

The importance of understanding intersectional and complex interactions among the drivers of vulnerability is now better reflected in recent progress in the IPCC AR6 risk framework (Simpson et al., 2021; Ara Begum et al., 2022). Two substantive advances to the

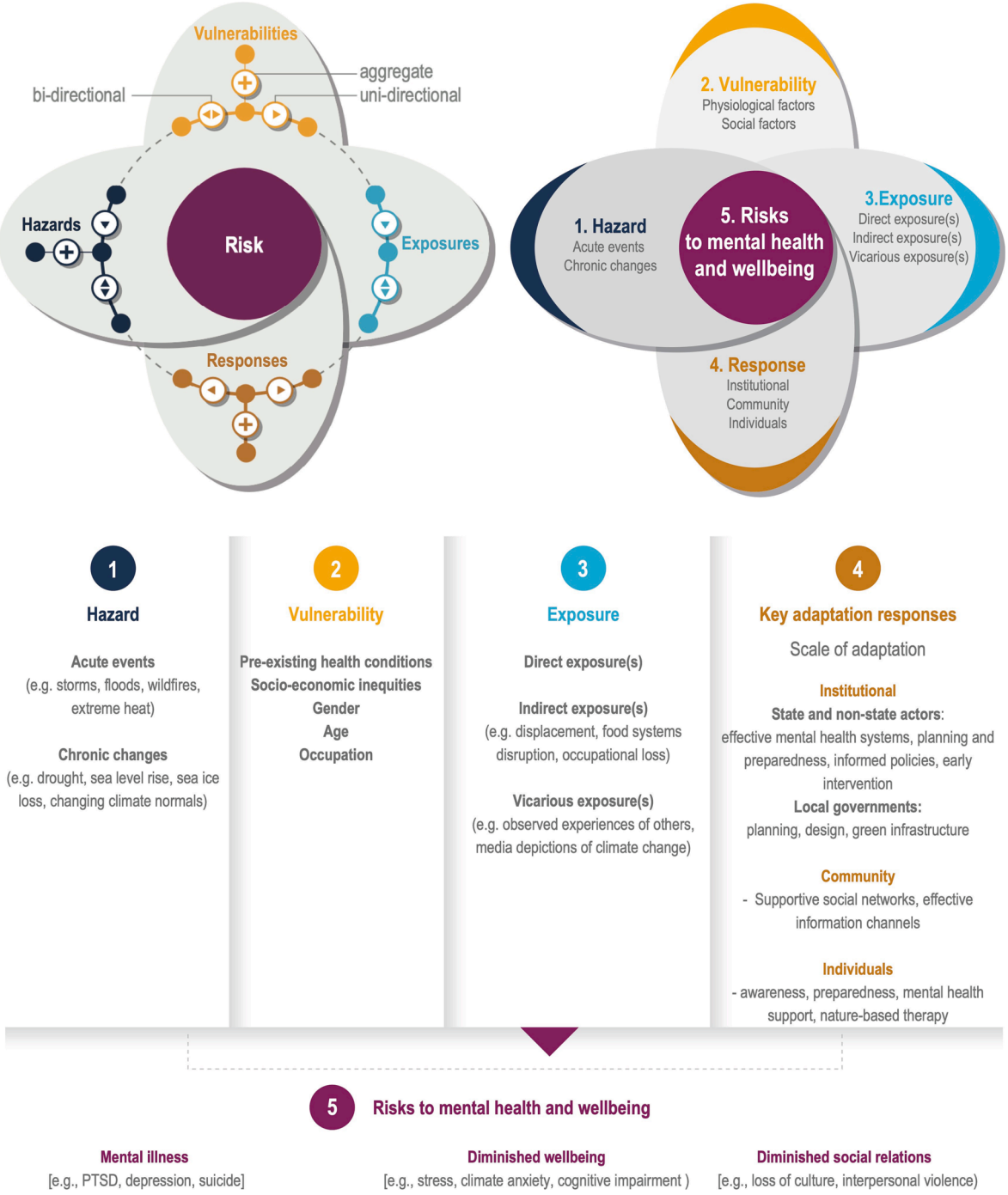

Fig. 2. Innovations to the IPCC assessment risk framework concerning multidimensional and intersectional vulnerability in the 6th Assessment Report (used with permission, Ara Begum et al., 2022; Cissé et al., 2022). This example illustrates how five dimensions of vulnerability – pre-existing health conditions, socio-economic conditions, gender, age and occupation – can aggregate or compound with each other or other determinants of risk to affect climate change impacts on mental health and key adaptation responses for PTSD: Post traumatic stress disorder (used with permission, Ara Begum et al., 2022; Cissé et al., 2022).

IPCC risk framework include recognition of multiple dimensions of vulnerability and the importance of responses as a determinant of risk. Fig. 2 highlights a new emphasis within the 'wings' of the hazards, vulnerabilities, responses, and exposures 'propellers' that explicitly recognises multiple drivers of risk (e.g., gender, migrant status, age) within each determinant and how they interact with each other, potentially in compounding ways. Integrating response within the IPCC risk framework is the future direction of IPCC risk assessment (Ara Begum et al. 2022). As risk assessment spans all three Working Groups of the IPCC, the differential role of risk determinants for risk related to impacts, adaptation, and vulnerability versus risk related to mitigation becomes an increasingly important feature of climate risk assessment as well as management.

The Africa Chapter of the IPCC Working Group II was the only chapter to explicitly set out its Vulnerability Synthesis using the new risk framework of AR6 that now includes risk from responses and recognises the multivariate drivers of risk as well as interactions between risks themselves (Trisos et al., 2022). In line with the evolution of the IPCC risk framework, each of these reframings contributes to our thinking about the drivers of vulnerability in Africa as well as the multiple axes of social difference along which vulnerability is distributed within different sub-regional and local contexts.

Fig. 2 highlights interactions among multiple risk drivers both within and across the determinants of risk. In revision of current concentration on compound climate extremes where two or more hazards interact to increase risk, equal attention is now given to interactions among multiple drivers of vulnerability, exposure, and responses (Simpson et al., 2021; Cissé et al., 2022) Such interactions include those among the multiple drivers of vulnerability and the specific intersections of gender, age, and race that are associated with, for example, increased risk of mortality and morbidity from extreme heat (Hallegatte et al., 2015). Importantly, it considers how key drivers of vulnerability interact with each other in aggregating, compounding or cascading ways with differential outcomes for climate change risk (Simpson et al., 2021; Simpson et al., 2023). Equitably addressing the vulnerability-related drivers of climate change risk under conditions of compound climate events is critically important as recent reviews have shown that current risk

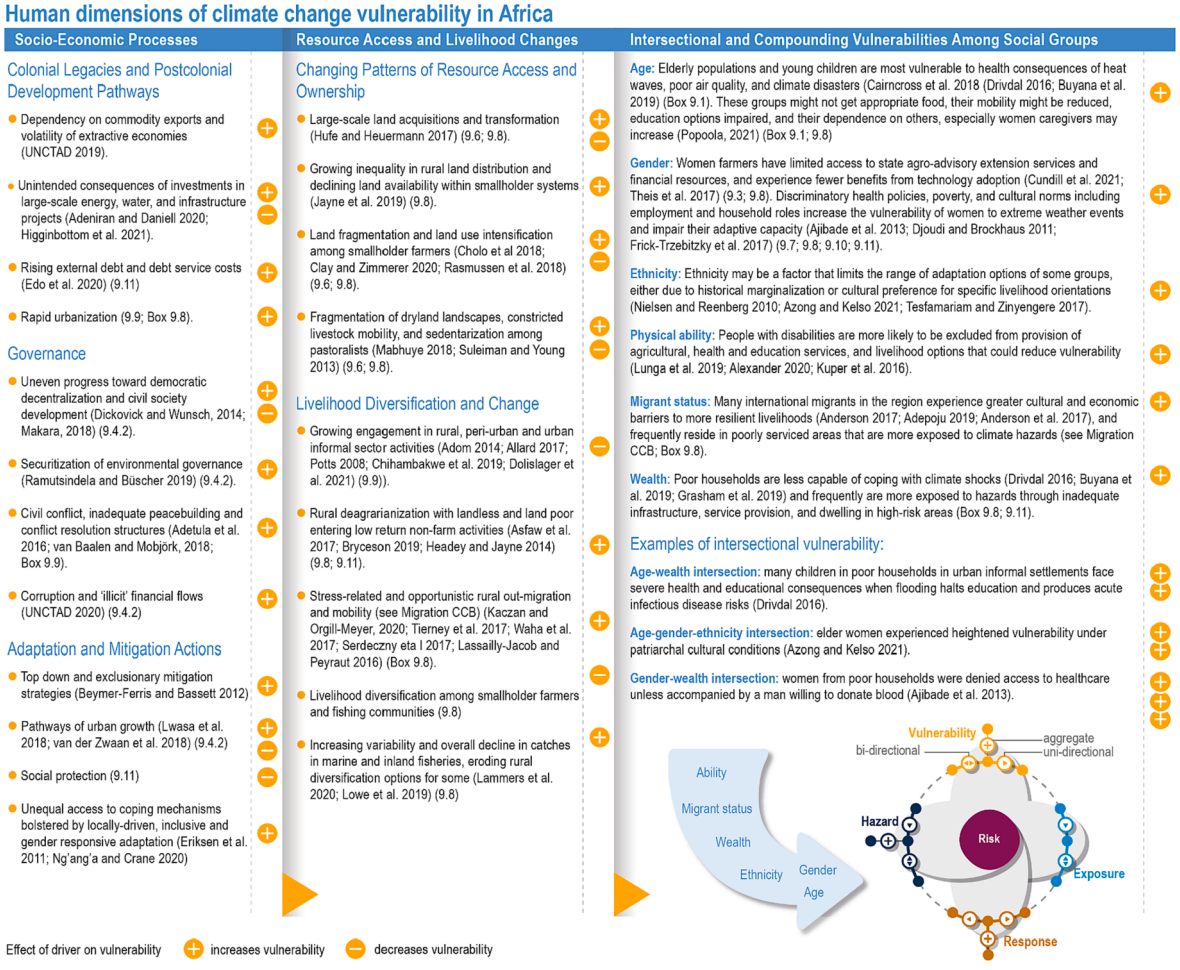

Fig. 3. Factors contributing to the progression of vulnerability to climate change in African contexts considering socioeconomic processes, resource access, livelihood changes, and intersectional vulnerability among social groups (used with permission, Trisos et al., 2022). This figure reflects a synthesis of vulnerability across sections of this chapter and highlights how the interactions of multiple dimensions of vulnerability compound each other to increase overall vulnerability (See above-mentioned references for further information.).

management strategies most often fail to reduce impacts of subsequent hazard events when they are more extreme than the initial hazard (Tellman and Eakin, 2022).

This is closer to a real-world experience of how vulnerability affects risk than previous formulations by the IPCC and elsewhere.This framework better aligns with advances in thinking around more active articulations of intersectionality (Versey, 2021), the need to unmask important differences between the individual drivers of vulnerability (Nyantakyi-Frimpong, 2020) and growing concern for risk from responses that exacerbate vulnerability (Eriksen et al., 2021; Simpson et al., 2023). These advances allow more appropriately targeted interventions on the most severe and pervasive drivers of vulnerability across specific contexts as well as inform vulnerability-specific safeguards in the choice between adaptation and mitigation responses to climate change. Here we seek to elaborate on dimensions of climate change vulnerability in Africa that require greater research attention. We highlight how these dimensions of vulnerability matter for adaptation to climate change and our understanding of the complexity of climate change risk.

3. Critical drivers of vulnerability to climate change in Africa

Fig. 3 provides an overview of how multiple drivers shape overall vulnerability and risks in the African regional context. While important macro socio-economic processes are listed individually, these drivers interact in shaping mesoscale systems of resource access and livelihood and the social differentiation of climate risk at the local level. For example, illicit financial flows and deepening external debts combine to weaken state capacity, hinder public investments in health and other social sectors, and likely discourage private investment (Ndikumana and Boyce, 2021; UNCTAD, 2020). The magnitude and impacts of illicit flows vary substantially by country, with the bulk of illicit capital flows from the region emanating from countries for which total exports are heavily weighted toward natural resources, such as mining products (South Africa, Democratic Republic of Congo, Botswana, and Zambia) and oil and gas (Nigeria, the Republic of the Congo, Angola, Sudan and Cameroon) (Signé et al. 2020). Such illicit flows of financial resources magnify the negative consequences of Africa's commodity dependency, pilfering state capacity and compounding the challenges of more inclusive governance (Reuter 2012). It further increases the likelihood that substantial sections of rural populations are excluded from the benefits of large infrastructure investments (Adeniran and Daniels 2012) or do not share broadly in the benefits of planned responses to climate change, related for example to renewable energy production (Ockwell et al. 2018) or technological investments in agriculture (Higginbottom et al., 2021). Delineating particular configurations of interacting external drivers is an important challenge for vulnerability assessments that seek to identify what hazards scholars have termed 'disaster risk creation' as opposed to assessments that focus more narrowly on proximate causes inferred from social patterns of vulnerability in local contexts (Hilhorst and Bankoff, 2022).

The colonial legacies of power imbalances and unequal trade relations are an example of cascading effects of vulnerability drivers over longer time scales that are pronounced in many African countries. In Ghana, for example, the stark North-South divide has its roots in an early colonial focus on extractive and agricultural development in the resource-rich South of the country (Ahmed et al., 2016), treating the North mainly as a reserve of cheap agricultural and non-agricultural labour (Songsore, 2003). The resulting lack of infrastructure in the North, and persistent patterns of out-migration leading to labour shortages contribute to vulnerability in this area with high rainfall variability still today (Nyantakyi-Frimpong and Bezner-Kerr, 2015). These structural factors also compounded with the effects of neoliberal reforms in the wake of the structural adjustment programs of the 1980s, when agricultural subsidies, extension services and smallholder support were substantially reduced; growing market integration benefited mostly larger and resource-rich farmers, further increasing inequality and rural poverty (Awanyo and Attua, 2018). The case of northern Ghana serves as an important reminder that the extent to which particular configurations of drivers matter varies substantially, not only by country but also at the subnational and local levels. The diversity of Africa's vulnerability contexts reinforces the need for nuanced and multi-scalar assessments that incorporate both responses and intersectional dynamics to explain propensity for harm as well as capacity to resist and mitigate climate impacts.

For most African countries, Nationally Determined Commitments (NDCs) under the Paris Agreement rest on growing investments in energy, water and agricultural infrastructure (England et al., 2018). These investments are part of a "global infrastructure turn" (Enns and Bersaglio, 2020). As one form of climate change response, these projects may compound with such inequalities and have differential and often overall negative effects on vulnerability if they cater to the economic and political interests of global capital and powerful national elites rather than to those of local populations. Similarly, the increasing integration of smallholder farmers into global value chains produces unequal benefits and vulnerabilities, often empowering and strengthening already powerful actors but leaving out the most vulnerable, or putting them into stronger relations of dependency, especially in technology transfer (Zylberberg, 2013; Ayanlade et al., 2022; Nega and Schneider, 2014). These structural influences and development dynamics at the macro level then compound with factors on the local level, for instance, the often high reliance on climate-sensitive activities and ecosystem services for livelihoods in many rural parts of Africa (Rippke et al., 2016). Adaptation responses to climate risks may likewise affect vulnerability and its drivers on micro and macro scale; an enhancement of vulnerabilities and their drivers is defined as a constituting element of maladaptation (Pörtner et al., 2022). This may entail reinforcing and redistributing existing vulnerabilities or creating new vulnerabilities (Eriksen et al., 2021).

Fig. 3 further emphasises the mediation of vulnerability through intersecting dimensions of social status such as gender, ethnicity, class, age, and disability (Luo et al., 2019; Prakash et al., 2022). Intersectional approaches to vulnerability seek to explicitly incorporate these multiple dimensions of social identity and status that are reflected in unequal power relations and differential access to resources and social networks essential to limiting climate impacts and adapting to new conditions (Djoudi et al., 2016; Nyasimi et al., 2018a; Prakash et al., 2022). Intersectional framings of vulnerability differ from those concerned with singular "vulnerable groups" in their concern for intra-group heterogeneity, their attention to the agency of the vulnerable, and their commitment to developing place-

based understanding of the means through which social categories are constructed (Djoudi et al., 2016; Kaijser and Kronsell, 2014).

Intersectional analyses may create opportunities to identify pathways for vulnerability reduction that do not merely "target" women or other socially defined groups as inherently vulnerable but rather take full stock of how gender is entwined with multiple, interacting forms of social identity and inequality that may either enable or constrict resource access. For example, how people experience climate vulnerability affects mobility decisions and unplanned climate mobility can result in new risks and vulnerabilities (Amakrane et al. 2023). Amongst the poorest households, women typically lack the resources that would allow them to migrate in ways that maintain an acceptable standard of living and may find themselves unable or unwilling to move in the face of climate change impacts (Prakash et al., 2022; Benveniste et al., 2022; Birkmann et al., 2022). In rural Mali, however, Djoudi and Brockhaus (2011) found paradoxically that women of lower social status had greater flexibility in taking on new livelihood roles following male out-migration, demonstrating the surprises that may emerge from dynamic and sometimes paradoxical vulnerability contexts. Intersectional vulnerability assessment provides the means to interpret such complexity in local contexts, including the ways in which capacities to resist, cope with and recover from climate-related hazards are enacted through forms of agency that transcend generalised identities and social categories (Kaijser and Kronsell, 2014).

Critics of the wider literature on climate vulnerability have cited a continued centering of physical climate hazards, static concepts of human-environment relationships, and the characterization of vulnerable populations as passive victims (Ford et al., 2018). Such critiques reflect a longstanding political-ecology concern for the multi-scale social drivers of vulnerability (Watts and Bohle, 1993) and more recent examination of the de-politicization of vulnerability and adaptation that diverts attention from solutions that address the underlying causes of vulnerability (Bassett and Fogelman, 2013; Ribot, 2014). These critiques have particular salience in the African regional context where the "naturalisation of vulnerability" has been recurrent in some policy and scholarly discourses (Ayanlade et al., 2020; Ribot, 2014; Smucker et al., 2015; Symons, 2014). Although we know the importance of understanding the complexity and intersectionality of vulnerability for informed adaptation, empirical research highlighting the intersectionality of vulnerability and its link to complex climate change risk in Africa remains limited.

Across these observations, three general themes become clear. First, multiple, interacting non-climatic factors play a key role in producing vulnerabilities. Often these processes are non-linear, defying simplistic and singular cause-effect explanations and can have compounding and cascading effects. Second, there are discernible macro-trends throughout the region including rapid urbanisation, population growth and growing inequality, but it is also evident that there is considerable internal diversity, with very specific constellations of vulnerability drivers in different national and regional settings. Third, there is a need for a better understanding of how the drivers and root causes of vulnerability are associated with or addressed by broader development trends in Africa and to integrate such understanding with analyses and models of hazards and exposure, as well as with the likely effects of mitigation and adaptation interventions, in order to avoid maladaptive outcomes.

4. Future directions for research

Although assessment of vulnerability is highly challenging in Africa, recent insights from vulnerability scholarship could drastically enhance understanding of the diversity of vulnerability drivers and responses across the region. Given the growing momentum of planned adaptation, there is a need to scale up capacity for vulnerability assessment that incorporates the insights identified above. Although there is no singular intersectional methodology related to climate vulnerability, we argue that a more explicit concern for interacting drivers and intersectional dynamics can be effectively incorporated into existing vulnerability assessment methodologies carried out by researchers and practitioners throughout the region. However, this will require a much broader inclusion of qualitative research methods and of indigenous and local knowledge, which are, despite their capacity to deliver robust and highly relevant results, still lacking recognition as valid methods in climate change research (Bercht 2021). Such analyses will also be essential to identifying opportunities for vulnerability reduction that cut across multiple axes of social difference and avoiding the real dangers of maladaptation (Schipper, 2020). Indeed, the growing evidence of maladaptive outcomes of planned adaptation points to an urgent need for substantially greater coverage of place-based vulnerability assessments representing critical transitions in socio-ecological systems across the continent (Ayanlade et al., 2020).

In order to expand geographic coverage of vulnerability assessment and realise benefits in terms of vulnerability reduction, greater coordination will be needed among national and international scientific organizations, civil society and non-governmental organizations, and policy communities. For example, the growing use of participatory vulnerability assessment by non-governmental organisations (e.g., Adem et al. 2017) could enable collation of findings and make possible *meta*-analyses that serve as important bridges between qualitative, community-based assessments and quantitative national or regional assessments of differential vulnerability, particularly when scoped to studies that can show the directionality and size of effects. Importantly, such an expansion of vulnerability research in the region will enable better understanding of the directionality of interactions between vulnerability and adaptation by considering the effect or potential feedback of individual vulnerabilities on specific responses or response bundles. At present there are vague notions that specific vulnerabilities and responses affect each other resulting in potential for maladaptation, but these lack specificity regarding the directionality and proportional effects and therefore their effect on overall risk. Across much of Africa, there are both qualitative and quantitative information gaps that require significant research investment. Lastly, longitudinal methodologies can further deepen understanding of the progression of vulnerability and its distribution over time (Fawcett et al., 2017). This would provide valuable insights for temporally compounding vulnerabilities, particularly under conditions of sequential climate events.

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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