



## Habitability for a connected, unequal and changing world

Harald Sterly<sup>a,\*</sup>, Marion Borderon<sup>a</sup>, Patrick Sakdapolrak<sup>a,b</sup>, Neil Adger<sup>c</sup>, Ayansina Ayanlade<sup>d,e</sup>, Alassane Bah<sup>f</sup>, Julia Blocher<sup>g</sup>, Suzy Blondin<sup>h</sup>, Sidy Boly<sup>i,j</sup>, Timothée Brochier<sup>k,l</sup>, Loïc Brüning<sup>m</sup>, Simon Bunchuay-Peth<sup>a</sup>, David O'Byrne<sup>n</sup>, Ricardo Safra De Campos<sup>c</sup>, Samuel Nii Ardey Codjoe<sup>o</sup>, Florian Debève<sup>p</sup>, Adrien Detges<sup>q</sup>, Maria Franco-Gavonel<sup>c,r</sup>, Claire Hathaway<sup>s</sup>, Nikki Funke<sup>t</sup>, François Gemenne<sup>p</sup>, Flore Gubert<sup>u,v</sup>, Eshetu Gurmu<sup>w</sup>, Rachel Keeton<sup>x</sup>, Boonthida Ketsomboon<sup>y</sup>, Marie Leroy<sup>z</sup>, Nassim Majidi<sup>aa,ab,ac</sup>, Sergio Marchisio<sup>ad,ae</sup>, Mumuni Abu<sup>o</sup>, Sopon Naruchaikusol<sup>y</sup>, Francesco Negrozio<sup>ad</sup>, Hervé Nicolle<sup>aa</sup>, Gianfranco Nucera<sup>ad</sup>, Lennart Olsson<sup>n</sup>, Jared Owuor<sup>aa</sup>, Pierre Ozer<sup>p</sup>, Etienne Piguet<sup>m</sup>, Diana Reckien<sup>x</sup>, Sarah Redicker<sup>c</sup>, Diogo Andreolla Serraglio<sup>g</sup>, Benjamin Sultan<sup>af</sup>, Dennis Tänzler<sup>q</sup>, Sara Vigil<sup>ag,ah</sup>, Kira Vinke<sup>ai</sup>, Karim Zantout<sup>g</sup>, Caroline Zickgraf<sup>p,r</sup>

<sup>a</sup> Department of Geography and Regional Research, University of Vienna, Vienna, Austria

<sup>b</sup> International Institute of Applied Systems Analysis, Laxenburg, Austria

<sup>c</sup> Department of Geography, Faculty of Environment, Science and Economy, University of Exeter, Exeter, UK

<sup>d</sup> Obafemi Awolowo University, Ile-Ife, Nigeria

<sup>e</sup> Central European University, Vienna, Austria

<sup>f</sup> Laboratory of Atmospheric and Ocean Physics, Cheikh Anta Diop University, UCAD, Ecole Supérieure Polytechnique, ESP, Dakar, Senegal

<sup>g</sup> Potsdam Institute for Climate Impact Research, Potsdam, Germany

<sup>h</sup> UER Didactics of Human and Social Sciences (SHS), University of Teacher Education, Lausanne, Switzerland

<sup>i</sup> National Statistical Institute of Mali, INSTAT, Bamako, Mali

<sup>j</sup> Integrated Development Authority of the Liptako-Gourma Member States (ALG), Ouagadougou, Burkina Faso

<sup>k</sup> UMMISCO, University of Sorbonne, National Research Institute for Sustainable Development, IRD, Bondy, France

<sup>l</sup> UMMISCO, Cheikh Anta Diop University, UCAD, Ecole Supérieure Polytechnique, ESP, Dakar, Senegal

<sup>m</sup> Institute of Geography, Faculty of Arts and Social Sciences, University of Neuchâtel, Neuchâtel, Switzerland

<sup>n</sup> Lund University Centre for Sustainability Studies, LUCSUS, University of Lund, Lund, Sweden

<sup>o</sup> Regional Institute for Population Studies, University of Ghana, Accra, Ghana

<sup>p</sup> Department of Geography and the Hugo Observatory, University of Liège, Liège, Belgium

<sup>q</sup> adelphi consult, Berlin, Germany

<sup>r</sup> School for Business and Society, University of York, York, UK

<sup>s</sup> United Nations Educational, Scientific and Cultural Organization, UNESCO, Paris, France

<sup>t</sup> British High Commission Pretoria, Pretoria, South Africa

<sup>u</sup> LEDa-DIAL, National Research Institute for Sustainable Development, IRD, PSL, Université Paris-Dauphine, CNRS, Paris, France

<sup>v</sup> Institut Convergences Migrations, CNRS, Aubervilliers, France

<sup>w</sup> Institute of Development and Policy Research, Addis Ababa University, Addis Ababa, Ethiopia

<sup>x</sup> Department of Urban and Regional Planning and Geo-Information Management, University of Twente

<sup>y</sup> Raks Thai Foundation, Bangkok, Thailand

<sup>z</sup> CARE France, Paris, France

<sup>aa</sup> Samuel Hall Research, Nairobi, Kenya

<sup>ab</sup> African Centre for Migration & Society, University of the Witwatersrand, Johannesburg, South Africa

<sup>ac</sup> Feinstein International Center, Tufts University, Boston, USA

<sup>ad</sup> Department of Political Science, Sapienza University of Rome, Rome, Italy

<sup>ae</sup> European Centre for Space Law, ECSL, European Space Agency, ESA, Paris, France

<sup>af</sup> ESPACE-DEV, University of Montpellier, National Research Institute for Sustainable Development, IRD, Montpellier, France

<sup>ag</sup> Stockholm Environment Institute, Asia Centre, Bangkok, Thailand

<sup>ah</sup> Chulalongkorn University Social Research Institute (CUSRI)

\* Corresponding author at: Department of Geography and Regional Research, University of Vienna, Universitätsstr. 5/7, 1010, Vienna, Austria.

E-mail address: [harald.sterly@univie.ac.at](mailto:harald.sterly@univie.ac.at) (H. Sterly).

## ARTICLE INFO

**Keywords:**  
 Habitability  
 Climate change  
 Culture  
 Inequality  
 Intersectionality  
 Connectivity

## ABSTRACT

As global climate change intensifies, the question of what makes a place habitable or uninhabitable is critical, particularly in the context of a potential future climate outside the realm of lived experience, and the possible concurrent redistribution of populations partly associated with such climatic shifts. The concept of habitability holds the potential for advancing the understanding of the societal consequences of climate change, as well as for integrating systemic understandings and rights-based approaches. However, most ways of analyzing habitability have shortcomings in terms of in-depth integration of socio-cultural aspects and human agency in shaping habitability, in failing to address spatial inequalities and power dynamics, and in an underemphasis of the connectedness of places. Here we elaborate habitability as an emergent property of the relations between people and a given place that results from people's interactions with the material and immaterial properties of a place. From this, we identify four axes that are necessary to go beyond environmental changes, and to encompass socio-cultural, economic, and political dynamics: First the processes that influence habitability require a systemic approach, viewing habitability as an outcome of ecological, economic, and political processes. Second, the role of socio-cultural dimensions of habitability requires special consideration, given their own operational logics and functioning of social systems. Third, habitability is not the same for everyone, thus a comprehensive understanding of habitability requires an intersectionally differentiated view on social inequalities. Forth, the influence of external factors necessitates a spatially relational perspective on places in the context of their connections to distant places across scales. We identify key principles that should guide an equitable and responsible research agenda on habitability. Analysis should be based on disciplinary and methodological pluralism and the inclusion of local perspectives. Habitability action should integrate local perspectives with measures that go beyond purely subjective assessments. And habitability should consider the role of powerful actors, while staying engaged with ethical questions of who defines and enacts the future of any given place.

## 1. Introduction

The increasing frequency and magnitude of extreme climatic events in recent years (Rodell & Li, 2023), and the related losses of lives and livelihoods have increased the attention to the escalating consequences of climate change (Steel et al., 2022). As climate mitigation efforts continue to lag behind the level necessary to limit global warming to 1.5 °C (UNEP, 2022), pressing questions about the limits of adaptation and humanity's ability to withstand the impacts of extreme climatic events are coming to the fore (Dow et al., 2013, IPCC, 2022). Studies project that large segments of the global population may be living outside the so-called human climate niche in the near future, if climate change mitigation remains insufficient for meeting the 1.5 to 2 degrees target (Xu et al., 2020, Lenton et al., 2023), and researchers warn that humanity might even face existential risks (Kemp et al., 2022). This is aggravated by the fact that climate is only one of the six dimensions where earth systems have already crossed planetary boundaries (Richardson et al., 2023). Although considerable uncertainty remains due to the complexities, contextualities, and non-linearities of the involved systems, shifts in the climate system—along with the crossing of planetary boundaries, and the resulting decline of habitats—are increasingly recognized as having the potential to increase displacement and migration on a larger scale (Black et al., 2011; O'Neill et al., 2022).

It is therefore not surprising that the concept of habitability is finding its way from astronomy into climate impact research (e.g. Storlazzi et al., 2015; Horton et al., 2021; Farbotko & Campbell, 2022). Earlier scholarship, such as Clarence Glacken's (1956) work on 'Changing Ideas of the Habitable World', has explored how human activities have historically shaped the habitability of landscapes. More recently, the concept has gained momentum in the climate and environmental sciences. Our contribution here focuses on the human dimensions—the habitability of a place for people—whilst acknowledging that habitability can be more holistically conceptualized as for all species. Astrobiological research on habitability, for example, did not reference on humans, but rather considers habitability for complex life in general (e.g. Langmuir & Broecker, 2012). A broader shift in many disciplines towards decentering human exceptionalism has also led to a more encompassing perspective on habitability and an emphasis of ecological interdependencies, for example in Environmental or Planetary

Humanities (e.g. Chakrabarty, 2021), Anthropocene Studies (e.g. Haraway, 2016), or Ecofeminism (e.g. Janicka, 2024).

At the same time, it is necessary to address also other existing limitations of approaches to habitability. Fleetwood's (2023) historical account of the concept of habitability highlights the persistent influence of geo-determinism in shaping discourses of habitability throughout history, with climate reductionism (Hulme, 2011) as an extreme expression. This determinism and reductionism are reflected in what Horton et al. (2021) call top-down approaches for assessing habitability. Such approaches often focus on single hazards, favor natural sciences, and involve the application of quantitative approaches, and thus tend to rely on uniform methodologies and generalizable assumptions at global and regional scales. It is acknowledged that other disciplines such as anthropology, or environmental history, place an emphasis on the role of cultural values, historical experiences, and human agency for the ways people perceive and adapt to environmental change. In natural science-driven approaches, these factors tend to remain underexplored.

Current approaches to habitability in the context of earth system changes have therefore several limitations, including a) their difficulty in considering local factors and place-specific characteristics that shape habitability; b) their lack of concepts to include human agency, historical contexts, and socio-cultural values; c) their inability to address local inequalities, power dynamics, and the political dimensions of habitability, and d) the unaccounted role of spatial connectedness and exchange.

We continue a trend to a more contextualized and nuanced conceptualization of habitability: Pavez (2024) shows how, during the sixteenth century, the ancient idea of habitable and uninhabitable spaces, according to climate and location, was replaced by the idea of the world as completely habitable—and exploitable. Franco Gavonel (2023) argues that habitability should not be seen as a binary (habitable or uninhabitable), but rather a continuum, characterized by thresholds and tipping points between different states. Horton et al. (2021; see also Wrathall et al., 2023) delineate three such dimensions of habitability, supported by the environmental conditions of a place: human safety and survival, livelihood security, and societies' collective capacity to adapt to environmental risks. In a similar manner, Vinke (2022) identifies four key dimensions of habitability decline: loss of territory, physiological limits, increased frequency of extreme events, and decreasing human

security. In 2022, the Åbo Akademi University developed an index tailored to measure the habitability of islands in Finland, based on 45 indicators in seven domains (Åbo Akademi University, 2022). And O'Byrne (2023) suggests moving from a descriptive to a normative understanding of habitability, adopting Amartya Sen's capability approach to define habitability as a set of freedoms.

The apparently increasing relevance of this concept and its emergence in the earth system research field prompt us, as a group of interdisciplinary researchers focused on mobility dimensions of climate change,<sup>1</sup> to reflect on the ways in which the complex environmental and social realities and their co-evolution can be considered more comprehensively. With this contribution, we do not aim to offer a narrowly defined, exclusionary, or comprehensive concept of habitability. Rather, building on Horton et al.'s (2021) call for the integration of top-down and bottom-up approaches to habitability, we seek to highlight key dimensions that are essential for conceptualizing habitability and its changes in a connected, unequal, and changing world. When considering these aspects, the concept of habitability can enhance the understanding of a broader range of societal consequences of environmental and climate change.

## 2. Refining the understanding of habitability

While the concept has evolved over time, one could argue that, in a more human-centric reading, habitability pertains to the suitability of a place to support human life and livelihoods. We propose to define habitability as the emergent property or quality of the relation between people and a place that provides individuals and communities with the capabilities to pursue and sustain healthy, meaningful, and dignified lives. Based on this understanding, we identify four conceptual axes that require further elaboration.

First, we need to go beyond mere physical attributes and environmental benchmarks to capture the complexity of the compounding and cascading processes behind losses of habitability. Socio-cultural, economic, and environmental factors, and their complex interplay are key constituents of habitability. It is therefore neither merely a product of a place's ecological and physical attributes, nor can it be understood as only socially constructed. It is instead co-constituted and emerging from people's interactions with, and their lived experiences, perceptions, and discourses of the material and immaterial properties of a place, including spiritual connections. And we need to do more than juxtaposing the local ("bottom-up") perspective and its granular details and insights with the systemic ("top-down") view and its context and overarching trends. To grasp the full picture, they need to be integrated in a manner that acknowledges the interplay and feedback between processes and structures between these scales (Horton et al., 2021), but also considers power relations, and differing ontologies.

Second, a comprehensive understanding of "habitability" also requires considering the role of the socio-cultural dimensions of habitability. Social structures and processes, culturally mediated interpretative schemata, and discourses are central to how environmental quality and its changes are perceived and reacted to. Similar changes in the physical environment can thus be perceived and evaluated very differently (Adger, 2000). Socio-cultural aspects require special consideration, given that the operational logics and functioning of social systems are partly very different from those of ecological and other systems (Olsson & Jerneck, 2018). An encompassing concept of habitability could help to bridge the chasm between environmental and techno-social perspectives.

Third, habitability is not homogeneously experienced; it varies across different intersectional social categories. This leads to critical questions about the role of power dynamics and rights in determining

<sup>1</sup> From the HABITABLE Project (Linking Climate Change, Habitability and Social Tipping Points: Scenarios for Climate Migration).

habitability and its consequences at local levels. Habitability must thus be seen as socially differentiated. Inhabitants of a place will conceive its habitability differently, depending on their positioning along axes of privilege, vulnerability and marginalization, and unequal access and control over resources. Habitability is conditioned by structural factors from the macro, micro to *meso*-level, but plays out on the micro-level.

And fourth, the habitability of a place cannot be seen in isolation from other, neighboring or distant places and processes. Instead, habitability is strongly influenced by connectivity across space and scales, through biophysical processes, economic market linkages, and flows of resources, people, ideas, and information. Such external influences can massively transform a place, making otherwise uninhabitable localities suitable for human settlements and livelihoods, or they can deteriorate a habitable place through exploitation or other destructive mechanisms.

In the following, we further elaborate on these four axes.

### 2.1. Going beyond environmental factors – the multiple causes of habitability loss

Changes in the climate as well as in other environmental dimensions represent important threats to habitability (Hermans & McLeman, 2021, Xu et al., 2020, Richardson et al., 2023). However, we argue that, to a considerable degree, habitability is also shaped by socio-economic and political factors: it needs to be understood as the outcome of processes on different spatial, social, and temporal scales, much like vulnerability. Wisner et al.'s (2004) model of the progression of vulnerability, or Trisos et al.'s (2022) perspective on the mechanisms of adaptation provide a basis for that.

On the macro scale, issues such as demography, inflation, and changing terms of trade, but also colonial legacies, postcolonial development pathways and neocolonialism, geopolitics, governance changes, urbanization, and unequal development pathways are influential processes. It is important to note that the exact constellation of drivers and root causes of habitability changes are specific to the regional and local contexts. A key challenge is to assess the relative importance of these variables to each other, and also their mutual influence on each other. On a micro- and *meso*-scale, structures and processes such as local conflicts, change in land ownership, livelihood diversification and change, resource access and ownership, institutional quality, productivity changes, infrastructure, mechanization, automation, and digitalization are important drivers that influence habitability.

The study of *social-ecological systems* (SES), and their interactions, dynamics, and resilience, can provide an important basis for understanding the complex and non-linear dynamics of changes in habitability (see e.g. Folke et al., 2016), especially aspects of non-linearity, multi-stability, interdependency, feedback-loops, thresholds and tipping points (Berkes & Ross, 2013). In order to comprehend the changes in SES and habitability, it is crucial to have significant insights into how these interactions work. Such a systemic understanding also helps to better capture the ways in which geo-ecological and social processes interact at the local to regional scale: they can *aggregate* (just adding up), but often their interactions are non-linear, for example when drivers mutually reinforce each other (*compounding*), or when effects *cascade* through different dimensions or scales of drivers (Simpson et al., 2021).

### 2.2. Addressing socio-cultural dimensions of habitability

Considering habitability as an emergent quality of place implies the need to systematically consider social fields with their own operational logic and functioning (Adger, 2000, Folke et al., 2016, Olsson and Jerneck, 2018). That the question of habitability is not linked to the physical and material dimension alone can be implied from the limits-of-adaptation literature. Adger et al., 2009b point out the importance of considering the social limits of adaptation, where the diverse and possibly contradictory values of involved actors are decisive. Based on

different case studies from Africa, Carr (2019:73) hypothesizes that “above very, very low material thresholds (i.e., starvation)”, social goals are prioritized over material goals. In most SES and resilience approaches, a rather functionalist notion of society dominates, putting an emphasis on the conditioning influence of institutions, norms and values. However, social research stresses the relevance of inequalities in endowment with resources and power, and of the struggles for domination and favorable positioning in social systems (Olsson et al., 2015). Moreover, perceptions, experiences and identities, but also practices, routines and discourses shape the way material and immaterial qualities of life, livelihoods and places are valued and appreciated. In many societies, spiritual connections to a place are a crucial part of people’s relationship with it, often involving ties to ancestors, totems, or deities bound to that location. These spiritual bonds can be far more important than material conditions.

The habitability of places thus is not just an outcome of their physical characteristics, but emerges from the various types of interactions of people with place (Turner & Turner, 2006). Structural factors play an important role in shaping the relation of people to a place, as well as their valued objectives. These factors include the immaterial and socio-cultural aspects of places, as well as the social structures that organize society and meaning-making in a specific location. Rules, norms, and traditions that are bound to specific places, and the meaning and relevance of place for individual and social identity, are also essential aspects to consider (Janoth et al., 2024). Socio-psychological aspects matter a lot for experiencing of a place as habitable, as the moderating influence of place attachment on migration decisions shows (Adams, 2016)—with however varying degrees of “attachment”, ranging from personal nostalgia, to deeper, ontological connections between people and place in some cultures, where they are considered mutually constitutive.

### 2.3. Considering intersectionality and social differentiation of habitability

Habitability is not uniform for a given place. As highlighted by McLeman (2011), even in extreme cases of environmental stress, places are rarely completely abandoned, as a place is very differentially habitable for people with different social, economic, physical and mental abilities to experience and interact with it. These abilities are shaped by intersecting dimensions of difference, dominance, exclusion, and marginalization that structure intra-community and intra-household inequalities; such as gender, age, caste, class, and disabilities. A definition of habitability must be accompanied by a rights-based approach to capture these differences. This could also imply that a region needs to be considered un- or less inhabitable if degradations are so severe that human rights are undermined for a particular subgroup of the local population.

The differentiated habitabilities result, among others from i) unequal ways in which people interact with place, resulting for example from different types of livelihoods (such as farmers or herders), or from unequal access to land with different properties and risk exposure), ii) the different degree to which changes of habitability affect people, depending on the social status and position of individuals and groups, and their endowment with material and immaterial resources; iii) unequal perception and conception of, and relation to or attachment to place, depending for example on unequal motility, mobility and access to (parts of) places, but also unequal participation in place-specific activities, processes, or rituals), iv) and unequal participation in discourses over the value and meaning of place, on future-making, and the positioning of self with regard to local society and place. Much like the intersectional understanding of vulnerabilities, an intersectional framing of the differences of habitability should go beyond singular “vulnerable groups” but look at intra-group heterogeneity, emphasize the scope of agency, and the mechanisms through which social categories are constructed and inequalities are maintained (Kaijser & Kronsell, 2014, Vigil, 2024).

### 2.4. Understanding the role of connectivity across space and scales

Places and societies never exist in isolation and without relations to other places, and omitting that from a conceptualization of habitability would be misleading. A relational perspective on place, across scales and space (Massey, 2005) helps to reveal the extent to which, and the mechanisms how, connectivity to other locations affect habitability (Adger et al., 2009a; Friis and Nielsen, 2019; Sakdapolrak et al., 2016). Adger et al. (2009a) identify three *mechanisms* of tele-connectivity: biophysical linkages and feedback; economic market linkages; and flows of resources, people, ideas, and information. These mechanisms are based on relational structures, for example, the location and the material and physical-natural properties of places; the meaning and symbolic value that a given place derives from the relation to other places (e.g. as an “outpost” in the vicinity to a national border); transportation and communication infrastructure, networks and hubs (roads, banks, phone centers, etc.); the immaterial infrastructure that connects a place to other places, for example through markets, trade networks and relations that enable the exchange of goods and finances; through international legal and institutional instruments like free movement and free trade agreements; or through (translocal) social networks to other places that emerge for example from migration.

Connectivities can have negative and positive outcomes. At a place initially deemed uninhabitable (for example due to high temperatures, lack of rainfall, etc.), external inputs, for example subsidized finances, energy, or technology for groundwater extraction and cooling, can create opportunities for human settlements and livelihoods, thus rendering it habitable. This also applies to the influence of migration and financial and social remittances for a place to stay habitable (Sakdapolrak et al., 2023). On the contrary, a (hitherto habitable) place can become so deteriorated through its embedding in national or global networks of resource exploitation that it is not considered as habitable by its population anymore. The relationality of places also implies that habitability can have a relative element to it; for example, the outbreak of conflict or war in a place might influence—positively or negatively—the perceived habitability in a neighboring place.

These outcomes of connectivities are shaped also by the *mode* by which actors—both from within and from outside of a given place—engage with that place. These can be a) supportive, when actors from outside (e.g. migrants and/or the state) send resources in order to sustain or increase wellbeing and livelihood security (and thus habitability); b) evasive, when actors from a place decide to or need to move when the habitability of a place deteriorates; c) exploitative, when actors inside or outside a place extract resources or labor from that place in unequal exchange relations; d) controlling, when powerful actors like states engage in exchange activities in order to establish or maintain territorial control or secure borders; e) undermining, when actors like states or powerful groups for example destroy infrastructure in a region or a place, to deliberately diminish its habitability.

## 3. Researching habitability

For putting the concept of habitability to fruitful use in research, the call by Horton et al. (2021) to combine “top-down” with “bottom-up” approaches is important. To adequately address changes in habitability, it is necessary to develop methodologies and create the necessary knowledge base for investigating also early stages and more gradual losses of habitability, in addition to studying cases of expected total loss of territories or survivability. To achieve this, we call to include the following aspects in the four fields detailed above.

First, we need to strive for methodological pluralism, which necessarily means inter- and transdisciplinary research. This should include quantitative data and methods (e.g. remote sensing data on the impacts of weather events and climate change, land degradation and biomass productivity, modeling of agricultural productivity, monitoring of changes in SES dynamics, etc.) as well as qualitative approaches (e.g.

ethnographic and narrative approaches, participatory and empowering approaches, discourse analysis, feminist political ecology, etc.) to identify the direct and indirect causes and drivers of habitability changes at different levels.

Second, it must include local perspectives, as the subjective and collective experience and understanding of changes in habitability of affected groups should be center stage. There are a number of well-established, locally-driven approaches to determining aspects such as wellbeing, adaptation goals, and other related dimensions, in the fields of research (e.g. the book on Indigenous Research Methodologies by [Smith, 1999](#)), as well as practice and policy (e.g. Participatory Learning and Action, PLA, as a widely employed approach, see [Mukherjee, 2003](#); or the framework for the inclusion of indigenous people in climate action laid out by [Cochran et al., 2013](#)). At a local level, [Yee et al. \(2022\)](#) explore the role of Vanua, a Fijian term that refers to the natural environment, social bonds and kinship ties, and spirituality, that communities use to resist to climate-related relocation. As an example on a global level, [Redvers et al. \(2022\)](#) present the formulation of determinants of planetary health from an Indigenous perspective, which were defined in consensus panels by representatives of 14 indigenous groups. While these approaches do not explicitly address habitability, they offer good starting points that can be adapted for this purpose.

Third, combining “top-down” and “bottom-up” involves more than juxtaposing different perspectives. Ontologically and epistemologically, the differences between knowledge systems can be so large that ‘integrating’ them might be very difficult, if not impossible. Worldviews that for example emphasize spiritual aspects of places may prove challenging to reconcile with the material and reductionist ontologies that are underlying the frameworks of vulnerability and adaptation assessments. The production of, and the relation between, ‘scientific’ and ‘non-scientific’ knowledge is shaped by power imbalances, which are rooted in larger scale social, political and economic inequities. Without acknowledging and addressing these power imbalances, attempts to integrate diverse forms of knowledge can obscure these inequities, and further entrench the marginalization of other knowledge forms ([Klenk & Meehan, 2015](#)). Successfully combining, or rather aligning, “top-down” and “bottom-up” therefore necessitates to recognize the validity of different knowledge systems, and to foster intercultural knowledge exchange and mutual learning ([Mazzocchi 2018](#)).

Fourth, the role of powerful actors and the politics of habitability need to be considered. States can declare or “make” places habitable, for example for the sake of claiming or securing territories, or, when declaring them uninhabitable, banning the movement of people to such a place, or even displacing people from it. Also, private actors, such as mining or forestry corporations, can make places habitable (e.g. by providing infrastructure for a mining town in otherwise barely inhabitable arctic or desert areas) or uninhabitable (e.g. through extractive activities or pollution) ([Lunstrum et al., 2016](#)). Since the qualities that make a particular place acceptable to live in are culturally and historically specific, we also need to engage with the changing meaning and experiencing of habitability ([Farbotko and Campbell, 2022](#)). Political economy and political ecology approaches help in identifying the drivers and root causes and the political levers that underlie changes in habitability, especially through uncovering power structures, inequalities, and dependencies ([Barau, 2023](#)).

Fifth, in order to make the concept applicable in the policy and legal domains, it will be important to find measures of (unin)habitability that go beyond purely subjective assessments. There are different ways to establish thresholds of habitability on a spectrum (from optimal to pessimal). They can be defined along the dimensions of habitability sketched above (e.g. loss of adaptive capacity – loss of livelihoods – loss of survival), or in the sense of Nussbaum’s capabilities and freedoms ([O’Byrne, 2023](#)). They can also be defined with reference to tipping points of the local social-ecological system, for example, when a system shifts to another equilibrium, or when the functioning and the potential to manage and influence the SES are changing. A promising approach is

also to include legal aspects, based on human rights. The linkage between climate impacts and fundamental rights is recognized by a growing number of examples in recent case-law, e.g. referring to the lack of adequate adaptation, or relocation, as a basis for ascertaining human rights and granting appropriate protection ([Ioane Teitiota v. New Zealand, 2020](#); [Daniel Billy and others v. Australia, 2023](#)).

Sixth, ethical aspects are fundamental: Researchers should be aware of the discourses on habitability and the positions of powerful actors, and what these might entail: Findings and recommendations should be checked for potentially negative consequences. It is essential to involve local actors, with due consideration of their socio-economic position, in such processes—and to thoroughly reflect on the question of who gets to define and determine (unin)habitability, and what political and social consequences this can have.

Seventh, the concept of habitability is at present discussed predominantly with reference to the most vulnerable places and people in the Global South. However, it would be of value to link this for example to discussions of demographic decline and shrinking cities / regions in general ([Reckien and Martinez-Fernandez, 2011](#)), which can provide valuable insights for the linkages of habitability and mobility in the context of climate change.

If we consider the social-ecological dynamics of habitability, its intersectional differentiation, the political ecology shaping its drivers, and its ethical dimensions, it can be a valuable concept for understanding and addressing challenges of resilient development. Especially in settings where the decline of habitability is not necessarily reaching the threshold of non-survivability, which is likely the case for many people on the planet, it is critical to recognize that such changes can still render areas uninhabitable for the most vulnerable; identifying such more subtle shifts early on can also serve as a crucial warning and for sensitizing stakeholders. Acknowledging the influence of teleconnectivities is also necessary to avoid overestimating a place’s habitability, when local changes might otherwise be masked by external influences such as external aid or remittances.

In the face of escalating climate and environmental change, alongside considerable uncertainties about the future of human and non-human wellbeing, an open and inclusive approach to habitability can be an essential tool for devising global, national, and localized ‘no-regrets’ actions that support climate-resilient development pathways.

#### CRediT authorship contribution statement

**Harald Sterly:** Writing – review & editing, Writing – original draft, Conceptualization. **Marion Borderon:** Writing – review & editing, Writing – original draft, Conceptualization. **Patrick Sakdapolrak:** Writing – review & editing, Writing – original draft, Conceptualization. **Neil Adger:** . **Ayansina Ayanlade:** Writing – review & editing. **Alasane Bah:** Writing – review & editing. **Julia Blocher:** Writing – review & editing, Conceptualization. **Suzu Blondin:** Writing – review & editing, Conceptualization. **Sidy Boly:** Writing – review & editing, Conceptualization. **Timothée Brochier:** Writing – review & editing. **Loïc Brüning:** Writing – review & editing. **Simon Bunchuay-Peth:** Writing – review & editing. **David O’Byrne:** Writing – review & editing, Conceptualization. **Ricardo Safra De Campos:** Writing – review & editing, Conceptualization. **Samuel Nii Ardey Codjoe:** Writing – review & editing, Conceptualization. **Florian Debève:** Writing – review & editing, Conceptualization. **Adrien Detges:** Writing – review & editing, Conceptualization. **Maria Franco-Gavonel:** Writing – review & editing, Conceptualization. **Claire Hathaway:** Writing – review & editing. **Nikki Funke:** Writing – review & editing, Conceptualization. **François Gemenne:** Writing – review & editing, Conceptualization. **Flore Gubert:** . **Eshetu Gurmu:** Writing – review & editing, Conceptualization. **Rachel Keeton:** Writing – review & editing, Conceptualization. **Boonthida Ketsomboon:** Writing – review & editing, Conceptualization. **Marie Leroy:** Writing – review & editing. **Nassim Majidi:** Writing – review & editing, Conceptualization. **Sergio Marchisio:** Writing – review &

editing. **Mumuni Abu:** Writing – review & editing, Conceptualization. **Sopon Naruchaikusol:** Writing – review & editing, Conceptualization. **Francesco Negozio:** Writing – review & editing, Conceptualization. **Hervé Nicolle:** Writing – review & editing, Conceptualization. **Gianfranco Nucera:** Writing – review & editing, Conceptualization. **Lennart Olsson:** Writing – review & editing, Conceptualization. **Jared Owuor:** Writing – review & editing, Conceptualization. **Pierre Ozer:** Writing – review & editing. **Etienne Piguet:** Writing – review & editing, Conceptualization. **Diana Reckien:** Writing – review & editing, Conceptualization. **Sarah Redicker:** Writing – review & editing, Conceptualization. **Diogo Andreolla Serraglio:** Writing – review & editing, Conceptualization. **Benjamin Sultan:** Writing – review & editing. **Dennis Tänzler:** Writing – review & editing, Conceptualization. **Sara Vigil:** Writing – review & editing, Conceptualization. **Kira Vinke:** Writing – review & editing, Conceptualization. **Karim Zantout:** Writing – review & editing, Conceptualization. **Caroline Zickgraf:** Writing – review & editing, Conceptualization.

### 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.

### Acknowledgements

H.S. led the writing. H.S., M.B. and P.S. conceptualized and wrote the first draft. W.N.A., J.B., S.Blon., S.Bol., D.O'B., R.S.d.C., S.N.A.C., F.D., A.D., M.F.-G., N.F., F.Gem., F.Gub., E.G., R.K., B.K., N.M., M.A., S.N., F.N., H.N., G.N., L.O., J.O., E.P., D.R., S.R., D.A.S., D.T., S.V., K.V., K.Z., C.Z. contributed to the conceptualization and to reviewing and editing the drafts. A.A., A.B., T.B., L.B., S.B-P., C.H., M.L., S.M., P.O., B.S. contributed to reviewing and editing the drafts.

This work has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 869395.

### Data availability

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

### References

- Åbo Akademi University, 2022. The Habitability Handbook. <https://www.abo.fi/en/centre-for-lifelong-learning/habitability/habitability-handbook/> (last accessed 13.09.2024).
- Adams, H., 2016. Why populations persist: Mobility, place attachment and climate change. *Popul. Environ.* 37, 429–448. <https://doi.org/10.1007/s11111-015-0246-3>.
- Adger, W.N., 2000. Social and ecological resilience: are they related? *Prog. Hum. Geogr.* 24 (3), 347–367. <https://doi.org/10.1191/030913200701540465>.
- Adger, W.N., Eakin, H.C., Winkels, A., 2009a. Nested and teleconnected vulnerabilities to environmental change. *Front. Ecol. Environ.* 7 (3), 150–157. <https://doi.org/10.1890/070148>.
- Adger, W.N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Naess, L.O., Wreford, A., 2009b. Are there social limits to adaptation to climate change? *Clim. Change* 93, 335–354. <https://doi.org/10.1007/s10584-008-9520-z>.
- Barau, A., 2023. Beyond Normal: Thinking About the Multi-dimensionalities of Distressed Habitability Landscapes in Dryland African Cities. PERN Cyberseminar Expert Paper. [https://www.populationenvironmentresearch.org/pern\\_files/statements/CyberseminarExpertPaper\\_Barau\\_Beyond\\_Normal.pdf](https://www.populationenvironmentresearch.org/pern_files/statements/CyberseminarExpertPaper_Barau_Beyond_Normal.pdf) (last accessed 25.09.2024).
- Berkes, F., Ross, H., 2013. Community Resilience: Toward an Integrated Approach. *Soc. Natur. Resour.* 26 (1), 5–20. <https://doi.org/10.1080/08941920.2012.736605>.
- Black, R., Bennett, S., Thomas, S., et al., 2011. Migration as adaptation. *Nature* 478, 447–449. <https://doi.org/10.1038/478477a>.
- Carr, E.R., 2019. Properties and projects: Reconciling resilience and transformation for adaptation and development. *World Dev.* 122, 70–84. <https://doi.org/10.1016/j.worlddev.2019.05.011>.
- Chakrabarty, D., 2021. *The Climate of History in a Planetary Age*. The University of Chicago Press.
- Cochran, P., Huntington, O.H., Pungowiyi, C., et al., 2013. Indigenous frameworks for observing and responding to climate change in Alaska. *Climatic Change* 120, 557–567. <https://doi.org/10.1007/s10584-013-0735-2>.
- Daniel Billy and others v Australia (Torres Strait Islanders Petition), CCPR/C/135/D/3624/2019, UN Human Rights Committee (HRC), 18 September 2023, <https://documents.un.org/doc/undoc/gen/g23/188/41/pdf/g2318841.pdf>.
- Dow K., Berkhout F., Preston, B.L., 2013. Limits to adaptation to climate change: a risk approach. *Curr. Opin. Env. Sust.* 5 (3–4), 384–391. doi: /10.1016/j.coust.2013.07.005.
- Farbotko, C., Campbell, J., 2022. Who defines atoll 'uninhabitability'? *Environ. Sci. Policy* 138, 182–190. <https://doi.org/10.1016/j.envsci.2022.10.001>.
- Fleetwood, L., 2023. Histories of habitability from the oukoumene to the Anthropocene. *WIREs. Clim. Change* 14 (5), 14:e840. <https://doi.org/10.1002/wcc.840>.
- Folke, C., Biggs, R., Norström, A.V., Reyers, B., Rockström, J., 2016. Social-ecological resilience and biosphere-based sustainability science. *Ecol. Soc.* 21 (3), 41. <https://doi.org/10.5751/ES-08748-210341>.
- Franco Gavonell, M., 2023. Thinking about habitability through the exploration of thresholds and tipping points in climate migration. PERN Cyberseminar Expert Paper. [https://www.populationenvironmentresearch.org/pern\\_files/statements/CyberseminarExpertPaper\\_MFG\\_Habitability\\_and%20Tipping.Points.pdf](https://www.populationenvironmentresearch.org/pern_files/statements/CyberseminarExpertPaper_MFG_Habitability_and%20Tipping.Points.pdf) (accessed last 25.09.2024).
- Friis, C., Nielsen, J.Ø. (Eds.), 2019. *Telecoupling. Exploring Land-Use Change in a Globalized World*. Springer International Publishing.
- Glacken, C.J., 1956. *Changing Ideas of the Habitable World*. In: Thomas, W.L. (Ed.), *Man's Role in Changing the Face of the Earth*. The University of Chicago Press, pp. 70–92.
- Haraway, D., 2016. *Staying with the Trouble: Making Kin in the Chthulucene*. Duke University Press. <https://doi.org/10.1215/9780822373780>.
- Hermans, K., McLeman, R., 2021. Climate Change, Drought, Land Degradation and Migration: Exploring the linkages. *Curr. Opin. Env. Sust.* 50, 236–244. <https://doi.org/10.1016/j.coust.2021.04.013>.
- Horton, R.M., de Sherbinin, A., Wrathall, D., Oppenheimer, M., 2021. Assessing human habitability and migration. Integrate global top-down and local bottom-up analyses. *Science* 372 (6548), 1279–1283. <https://doi.org/10.1126/science.abi8603>.
- Hulme, M., 2011. Reducing the Future to Climate: A Story of Climate Determinism and Reductionism. *Osiris* 26 (1), 245–266. <https://doi.org/10.1086/661274>.
- Ioane Teitiota v. New Zealand, CCPR/C/127/D/2728/2016, UN Human Rights Committee (HRC), 7 January 2020, <https://documents.un.org/doc/undoc/gen/g20/237/12/pdf/g2023712.pdf>.
- IPCC, 2022. *Climate Change 2022: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegria, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, UK and New York, NY, USA. doi: 10.1017/9781009325844.
- Janicka, I., 2024. Habitability: Planetarity vs Cosmopolitics. *Migrat. Minds* 2 (1), 4–25. <https://doi.org/10.57928/pfqt-0116>.
- Janoth, J.N., Abu, M., Sakdapolrak, P., Sterly, H., Merschroth, S., 2024. The impact of migration on culturally-embedded and subjective perceptions of habitability in a context of environmental change: A case study from Northern Ghana. *Erdkunde* 78 (1), 35–55. <https://doi.org/10.3112/erdkunde.2024.01.02>.
- Kajiser, A., Kronsell, A., 2014. Climate change through the lens of intersectionality. *Environ. Polit.* 23, 417–433. <https://doi.org/10.1080/09644016.2013.835203>.
- Kemp, L., Xu, C., Depledge, J., Ebi, K.L., Tibbins, G., Kohler, T.A., Rockström, J. et al., 2022. Climate Endgame: Exploring catastrophic climate change scenarios. *PNAS* 119, e2108146119. doi: 10.1073/pnas.2108146119.
- Klenk, N., Meehan, K., 2015. Climate change and transdisciplinary science: Problematizing the integration imperative. *Environ. Sci. Policy* 54, 160–167. <https://doi.org/10.1016/j.envsci.2015.05.017>.
- Langmuir, C.H., Broecker, W., 2012. *How to build a habitable Planet*. Princeton University Press.
- Lenton, T.M., Xu, C., Abrams, J.F., Ghadiali, A., Loriani, S., Sakschewski, B., Zimm, C., et al., 2023. Quantifying the human cost of global warming. *Nat. Sustain.* 6, 1237–1247. <https://doi.org/10.1038/s41893-023-01132-6>.
- Lunstrum, E., Bose, P., Zalik, A., 2016. Environmental displacement. *Area* 48, 130–133. <https://doi.org/10.1111/area.12193>.
- Massey, D., 2005. *For space*. SAGE, London.
- Mazzocchi, F., 2018. Under What Conditions May Western Science and Indigenous Knowledge Be Jointly Used and What Does This Really Entail? Insights from a Western Perspectivist Stance. *Soc. Epistemol.* 32 (5), 325–337. <https://doi.org/10.1080/02691728.2018.1527412>.
- McLeman, A., 2011. Settlement abandonment in the context of global environmental change. *Global Environ. Chang.* 21 (S1), S108–S120. <https://doi.org/10.1016/j.gloenvcha.2011.08.004>.
- Mukherjee, N., 2003. *Participatory Learning and Action. With 100 Field Methods*. Concept Publishing Company, New Delhi.
- O'Byrne, D., 2023. Habitability as capability: proposing a normative definition of the concept. PERN Cyberseminar Expert Paper. [https://www.populationenvironmentresearch.org/pern\\_files/statements/CyberseminarExpertPaper\\_DOB\\_Habitability\\_as\\_capability.pdf](https://www.populationenvironmentresearch.org/pern_files/statements/CyberseminarExpertPaper_DOB_Habitability_as_capability.pdf) (accessed last on 25.09.2024).
- Olsson, L., Jerneck, A., 2018. Social fields and natural systems: integrating knowledge about society and nature. *Ecol. Soc.* 23 (3), 26. <https://doi.org/10.5751/ES-10333-230326>.
- Olsson, L., Jerneck, A., Thorén, H., Persson, J., O'Byrne, D., 2015. Why resilience is unappealing to social science: theoretical and empirical investigations of the scientific use of resilience. *Sci. Adv.* 1 (4), e1400217. <https://doi.org/10.1126/sciadv.1400217>.

- O'Neill, B., van Aalst, M., Zaiton Ibrahim, Z., Berrang Ford, L., Bhadwal, S., Buhaug, H., Diaz, D., et al., 2022. Key Risks Across Sectors and Regions. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Lösschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2411–2538, doi: 10.1017/9781009325844.025.
- Pavez, M.O., 2024. Habitability as a historical category for interpreting the Anthropocene. *J. Hist. Geogr.* 83, 96–109. <https://doi.org/10.1016/j.jhg.2023.12.002>.
- Reckien, D., Martinez-Fernandez, C., 2011. Why Do Cities Shrink? *Eur. Plan. Stud.* 19 (8), 1375–1397. <https://doi.org/10.1080/09654313.2011.593333>.
- Redvers, N., Celidwen, Y., Schultz, C., Horn, O., Githaiga, C., Vera, M., Perdrisat, M., et al., 2022. The determinants of planetary health: an Indigenous consensus perspective. *Lancet Planet. Health* 6 (2), e156–e163. [https://doi.org/10.1016/S2542-5196\(21\)00354-5](https://doi.org/10.1016/S2542-5196(21)00354-5).
- Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S., Donges, J.F., et al., 2023. Earth beyond six of nine planetary boundaries. *Sci. Adv.* 9, eadh2458. <https://doi.org/10.1126/sciadv.adh2458>.
- Rodell, M., Li, B., 2023. Changing intensity of hydroclimatic extreme events revealed by GRACE and GRACE-FO. *Nat. Water* 1, 241–248. <https://doi.org/10.1038/s44221-023-00040-5>.
- Sakdapolrak, P., Naruchaikusao, S., Peth, S.A., Porst, L., Rockenbauch, T., Tolo, V., 2016. Migration in a changing climate. Towards a translocal social resilience approach. *Die Erde* 147, 81–94. <https://doi.org/10.12854/erde-147-6>.
- Sakdapolrak, P., Borderon, M., Sterly, H., 2023. The limits of migration as adaptation. A conceptual approach towards the role of immobility, disconnectedness and simultaneous exposure in translocal livelihoods systems. *Clim. Dev.* 16 (2), 87–96. <https://doi.org/10.1080/17565529.2023.2180318>.
- Simpson, N.P., Mach, K.J., Constable, A., Hess, J., Hogarth, R., Howden, M., Lawrence, J., et al., 2021. A framework for complex climate change risk assessment. *One Earth* 4 (4), 489–501. <https://doi.org/10.1016/j.oneear.2021.03.005>.
- Smith, L.T., 1999. *Decolonizing Methodologies*. University of Otago Press, Research and Indigenous Peoples.
- Steel, D., DesRoches, C. T., Mintz-Woo, K., 2022. Climate change and the threat to civilization. *PNAS* 119(42), e2210525119. doi: 10.1073/pnas.2210525119.
- Storlazzi, C., Elias, E., Berkowitz, P., 2015. Many Atolls May be Uninhabitable Within Decades Due to Climate Change. *Sci Rep* 5, 14546. <https://doi.org/10.1038/srep14546>.
- Trisos, C. H., Adelekan, I. O., Totin, E., Ayanlade, A., Efitre, J., Gemed, A., Kalaba, K., et al., 2022. Africa. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Lösschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, 1285–1455. doi: 10.1017/9781009325844.011.
- Turner, P., Turner, S., 2006. Place, sense of place, and presence. *Presence Teleop. Virt.* 15 (2), 204–217. <https://doi.org/10.1162/pres.2006.15.2.204>.
- United Nations Environment Programme UNEP, 2022. Emissions Gap Report 2022: The Closing Window — Climate crisis calls for rapid transformation of societies. Nairobi. <https://www.unep.org/emissions-gap-report-2022> (last accessed on 26.09.2024).
- Vigil, S., 2024. Towards a feminist political ecology of migration in a changing climate. *Geoforum* 155, 104076. <https://doi.org/10.1016/j.geoforum.2024.104076>.
- Vinke, K., 2022. *Sturmnomaden*. dtv, Munich.
- Wisner, B., Blaikie, P., Cannon, T., Davis, I., 2004. *At Risk: Natural Hazards, People's Vulnerability and Disasters*. Routledge, London.
- Wrathall, D., de Sherbinin, A., Oppenheimer, M., Horton, R., 2023. Defining Habitability. PERN Cyberseminar Expert Paper. [https://www.populationenvironmentresearch.org/pern\\_files/statements/CyberseminarExpertPaper\\_Wrathall\\_et\\_al\\_Habitability.pdf](https://www.populationenvironmentresearch.org/pern_files/statements/CyberseminarExpertPaper_Wrathall_et_al_Habitability.pdf) (last accessed 26.09.2024).
- Xu, C., Kohler, T.A., Lenton, T.M., 2020. Future of the human climate niche. *PNAS* 117 (21), 11350–11355. <https://doi.org/10.1073/pnas.1910114117>.
- Yee, M., McNamara, K.E., Piggott-McKellar, A.E., McMichael, C., 2022. The role of Vanua in climate-related voluntary immobility in Fiji. *Front. Clim.* 4, 1034765. <https://doi.org/10.3389/fclim.2022.1034765>.