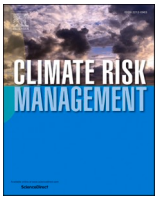
Climate Risk Management 48 (2025) 100712

Contents lists available at ScienceDirect

Climate Risk Management

journal homepage: www.elsevier.com/locate/crm



# Everyone's Adaptation: Exploring individual heat stress adaptation

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ARTICLE INFO

*Keywords:*
Everyone's adaptation (EoA)
Integrated framework
Individual and community agency
Collective facilitation and adaptation
Heat stress

ABSTRACT

Due to rising temperatures, heat stress affects nearly everyone's way of living. Adapting to heat stress is very individual, but our understanding of the process and conditions that influence such individual adaptation remains fragmented and limited. To address this knowledge gap, we introduce a novel conceptual framework, "Everyone's Adaptation (EoA),". This framework integrates insights from a range of inter- and *trans*-disciplinary concepts and theories from the individual to the collective level to explore the conditions under which individuals of all ages, genders, ethnicities, cultural and socioeconomic backgrounds can adapt to heat stress. We argue that a better understanding of the key enabling and constraining conditions at individual and community levels, and fair and equitable governance, can inform sustainable, effective, and fair climate change adaptation policies. In this paper, we operationalize the EoA framework in the context of heat stress adaptation. We propose this framework can also be adapted for adaptation to other extreme climatic events in various local contexts.

## 1. Introduction

Heat stress has recently gained considerable attention since global temperatures reached unprecedented levels in 2023 and 2024, with each month from June 2023 to June 2024 setting a new global record (Cattiaux et al., 2024). Notably, the annual average temperature for 2023 approached 1.5 °C above pre-industrial levels. Consequently, 2024 experienced record-breaking global temperatures, becoming the first year with an average temperature significantly exceeding 1.5 °C above pre-industrial levels (Cattiaux et al., 2024; Copernicus Climate Change Service, 2025). If current trends continue, global temperatures could rise by an estimated 4–5 °C by the end of this century (Tollefson, 2020; Durhasan et al., 2025). This increasing temperature impacts people in both the global South and North. Notably, people in cool regions have also begun dealing with heat and cold stress caused by climate change (Wan et al., 2023). Besides the evident need to mitigate global warming, decisions regarding socioeconomic development paths and adaptation strategies have been recognized as crucial factors determining the extent of heat-induced impacts on health and livelihoods (IPCC, 2023). Thus, understanding how extreme heat impacts populations is crucial for informing policies to reduce heat-related risks. Further research is needed on how to address the detrimental effects of heat stress on livelihoods and physiological wellbeing (Chazalnoël et al., 2017; Letsch et al., 2023).

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https://doi.org/10.1016/j.crm.2025.100712
Received 3 October 2024; Received in revised form 16 March 2025; Accepted 23 April 2025
Available online 26 April 2025

People use various strategies to cope with excessive heat, adjusting their daily lives to reduce vulnerability. Vulnerability varies due to factors like ethnicity, gender, age, and socioeconomic status. Women, especially pregnant women, and those with chronic illnesses, as well as older adults and children are particularly susceptible to heat stress (Baharav et al., 2023; Wallenberg et al., 2023; Meade et al., 2020; Kenny et al., 2010). Further, natural resource-dependent and low-income individuals, including those in informal settlements, are more exposed to extreme heat, which severely impacts their livelihoods (Adegun et al., 2022; Begum, 2023). As heat stress intensifies vulnerability across all groups, understanding how each individual adapts is crucial for ensuring sustainable development amid climate change (Sandholz et al., 2021). Thus, we define Everyone's Adaptation (EoA) as a conscious or unconscious act by which each person adapts to the current and future threats of climate change through incremental or fundamental modifications of their way of living. Here, everyone means individuals of different ages, genders, races, socioeconomic conditions, education, and cultural backgrounds, and their way of living refers to their place-based livelihood conditions. EoA is a comprehensive framework that provides a structured approach to understanding individual adaptation within household and community with collective facilitation interventions by drawing insights from cross-disciplinary literature review, for instance, climate change adaptation, public health, adaptation behavior, occupational safety, urban planning and environmental governance.

Adaptation to heat stress occurs at multiple scales. Health departments in Europe, America, and Asia advise outdoor workers to stay hydrated, rest, and seek cool areas to prevent heat stress (Rowlinson et al., 2014). Similarly, the WHO (2011) recommends keeping homes cool, staying out of the heat, staying hydrated, and helping people at risk during heat waves. Individuals often adapt to heat stress through spontaneous actions like drinking more water, wearing cotton clothes, and avoiding peak heat times (Kiarsi et al., 2022). This is known as autonomous adaptation, an immediate, impromptu response to extreme events (Smit et al., 2000; IPCC, 2007). In contrast, planned adaptation involves deliberate, policy-driven measures by governments (IPCC, 2007). Current climate policies focus more on planned adaptations rather than supporting individual, spontaneous efforts, which may lead to maladaptation by creating dependence on external resources (Rahman & Hickey, 2019; Thorn et al., 2015). More analysis is needed to balance both approaches.

Again, awareness of heat-stress adaptation varies by socioeconomic, educational, and cultural backgrounds, leading to different vulnerability levels. Both individual actions and community capacity are crucial for adapting to climate change (Castro & Sen, 2022). Individuals need various resources to build their capacity at both personal and community levels (Khalil & Jacobs, 2021). Effective and just governance can enhance individual adaptation, but equally, poor governance can stymie individual efforts and lead to increased vulnerability (Reckien et al., 2023, Juhola et al., 2022; Mees et al., 2014a). However, individual-level adaptation, particularly across diverse conditions and demographics, remains underexplored. Importantly, limited scholarly attention has been given to the individual level, focusing on minor incremental daily life adjustments and emphasizing individual and community capacity, notably social capital (Castro & Sen, 2022). Thus, there is a pressing need for a more detailed understanding of individual-level heat stress adaptation, particularly with respect to their varying vulnerability levels.

Our concept EoA, therefore, aims to explore all such conditions at individual, community, and collective levels. Individual adaptation within a household is distinct, while community-level initiatives, which operate beyond the household without external influence, can significantly impact personal adaptation. On a broader scale, collective adaptation involves measures taken by both governmental and non-governmental organizations. Our proposed framework is an example of a bottom-up approach that seeks to understand and account for how each of these individual, community, and collective levels interconnect to influence EoA. We integrate the conditions of different existing theories and concepts, for instance, 'livelihood resilience (LR)', 'place relations (PR)', 'Protection Motivation Theory (PMT)', 'Common-pool resources', 'Accessibility', and 'climate justice (CJ)' to enable an inclusive and comprehensive exploration of individual adaptation conditions at different levels. We unpack these concepts and theories in the next section based on their theoretical relevance to EoA, where a range of published studies related to these concepts have been synthesized to develop the conceptual framework of EoA. This is followed by the operationalization of EoA, through analyzing relevant empirical studies on heat stress adaptation in section three; and assessing the overall applicability of the framework in section four. Finally, in section five we discuss further implications of EoA. We argue, EoA differs from existing frameworks by offering a multi-level, interconnected approach that shows how different conditions influence individual adaptation. This makes EoA a more inclusive, equitable framework for managing climate stress, especially in vulnerable communities.

## 2. Theoretical integration for Everyone's adaptation (EoA)

Most individuals are part of a society, and their livelihood conditions lie at different opportunities and constraints in their respective social system, which in turn contour the individual's adaptation aspirations and capacities. This social system within which individuals are variously embedded can be understood through three distinct but integrated levels. Firstly, everyone has their own degree of agency, i.e., capacity or traits within their household; secondly, everyone is part of the community where they live and shares common resources (i.e., community agency); and thirdly, everyone is part of the large-scale initiatives at the collective level where governments formulate policies, and local governments, non-governmental organizations (NGOs)/community-based organizations (CBOs) take adaptation measures (i.e., conditions that address effectiveness and equity in governance). Given this multi-scale view, we integrate diverse relevant theories and concepts to explore the conditions of EoA and formulate an integrated framework where relevant conditions at the individual, community and collective level can be explored together. It is essential to study not only the importance of each condition, but also their combined effect to explore synergies and trade-offs between them. This can be done through, for instance, a Qualitative Comparative Analysis (QCA) (Ragin, 1987; Rihoux & Ragin, 2009), which allows researchers to analyze necessary and sufficient conditions for a particular outcome, in our case EoA. In the following subsections, we unpack the concepts related to individual and community agency, and collective conditions, which inform our EoA framework.

### 2.1. Individual agency

According to the Motivation-capacity-ownership (MCO) framework of Mees (2022), individuals' motivation-capacity-ownership to take climate actions are key conditions at the individual level. In other words, individuals need to be willing, able and feel responsible to act on climate change: their motivation, resources and sense of responsibility influence their willingness, ability, and ownership respectively (Mees, 2022). We have used these three dimensions as the basis for the individual-level conditions of our framework.

In the context of climate change adaptation, individual *motivation* depends on an individual's perception of their own risk and how this influences them to take actions. To understand this dimension of the individual-level conditions, our framework draws on Protection Motivation Theory (PMT). PMT was originally developed by Rogers (1975) in health psychology to analyze the motivation for self-protection through risk perception and coping ability (Mallick et al., 2022). PMT poses two key conditions for self-protection: threat appraisal and coping appraisal. Threat appraisal or risk perception varies from person to person, depending on how they understand and respond to an event. If they perceive risk from an extreme event, coping appraisal determines their decision-making. This comprises perceived self-efficacy (their belief in their ability to take meaningful action), and perceived response-efficacy (belief in the effectiveness of those actions); together, these factors contribute to individuals' willingness to act (Mallick et al., 2022). Individuals' protection motivation also depends on their aspiration to improve living conditions to better protect themselves from extreme events. Their capacity equips them to formulate and realize these better alternatives (Müller-Funk et al., 2023).

Capacity is defined in the livelihood approach as "assets (stores, resources, claims, and access) and activities required for a means of living" (Chambers & Conway, 1991, p. 6). Individuals' *resources* and living strategies contribute to their adaptation to extreme events (Lecegui et al., 2022). These contribute to livelihood resilience (LR), "the capacity of all people across generations to sustain and improve their livelihood opportunities and wellbeing despite environmental, economic, social, and political disturbances" (Tanner et al., 2015, p. 23). The LR concept has been employed in household-level vulnerabilities and resilience analysis (Ao et al., 2022; Mallick et al., 2020; Manlosa et al., 2019; Adu et al., 2018). Here, human capital denotes individuals' education, knowledge, skills, workability, and health conditions; and economic capital denotes the sources of finance (Department for International Development, 2001). These are the individual resources, called socio-demographic characteristics, which contribute to the adaptation to extreme events (Hota & Behera, 2014). Furthermore, individuals within households possess intergenerational learning potential, constituting intellectual capital that shapes personal coping strategies for extreme events (Mallick & Hunter, 2024; Tambaum, 2022). This mutual learning dynamic involves younger generations learning from older ones and vice versa. Knowledge transmitted across generations influences current practices, impacting individual adaptation processes (Berger et al., 2022; Warmuth et al., 2021). For instance, individuals may emulate the livelihood and coping strategies of previous generations, with family attitudes and values playing a significant role in the transmission of knowledge. Therefore, intergenerational learning is another essential individual resource influencing an individual's capacity to adapt to heat stress.

Most individuals are attached to a place; therefore, place-making is deeply connected to the individual's daily life, which helps to grow the *sense of place* (Willox et al., 2012). Sense of place is the physical and emotional connection to a place that develops over time in combination with place identity, place attachment, and place dependence (Sultana, 2023; Erfani, 2022; Rabbani et al., 2022; Nicolosi & Corbett, 2018; Tuan, 1974). When an individual stays in place longer, they typically form an attachment as they become accustomed to its particular conditions and depend on the facilities it offers. Usually, this place dependency refers to land tenure or longer-term living in the same place in addition to the affective dimensions of place (Khalil & Jacobs, 2021; Mulvaney et al., 2020; Adams & Adger, 2013; Jorgensen & Stedman, 2001). The sense of place and embeddedness invested by long-term living in a locale helps individuals to stay and adapt to adverse circumstances, including by taking protective measures against extreme events (Daly et al., 2022; Adie, 2020; Bosello et al., 2018).

The conditions derived from the theories and concepts described above – protection motivation, individual resources, and sense of place – determine the individual agency, i.e., the willingness and ability of an individual to act independently (see Table 1). In a more comprehensive way, individual agency is the capability of setting goals, planning, and taking actions in pursuit of an outcome currently and in the future, as well as regulating actions (Schoon & Heckhausen, 2019). Thus, individual agency is essential for daily adaptation to climatic hazards, namely heat stress.

### 2.2. Community agency

Not only individual agency, but also community capacity is crucial for reorganizing and prioritizing daily activities in response to climate change (Castro & Sen, 2022). Cobigo et al. (2016, p. 192) defined community as "a group of people that interact and support each other, and are bounded by shared experiences or characteristics, a sense of belonging, and often by their physical proximity". Thus, community agency inflects individual agency. For instance, *social capital*, particularly in the form of advantageous social relationships, is vital for enhancing adaptive capacity (Adger, 2010; Pelling & High, 2005). Putnam (1995) distinguishes two types of interpersonal relationships, are the key indicators of social capital: bonding indicates ties between religious or ethnic groups strongly influenced during conflict resolution and disaster recovery, whereas bridging ties denote associations between people with shared interests. Linking is a sub-category of bridging ties representing the relationships across groups in a vertical direction e.g., between community groups and donors (ibid). Social networks play an important role in community action. People share their resources with community members, for instance, by assuming responsibility for bringing them water from afar to overcome the drinking water crisis during summer (Abid et al., 2017). Likewise, Castro & Sen (2022) find that good relationships with neighbors lead to people helping one another during times of stress, for example, if someone cannot cook due to illness, their neighbors help them cook or share food with them.

**Table 1**
Interrelated conditions of EoA framework.

| Conditions | Indicators | Examples related to heat stress as reported in the literature |
|---|---|---|
| **Individual Agency** | | |
| Protection motivation | Self-efficacy, i.e., belief in self-ability to take actions | Taking simple actions to protect oneself (McLoughlin et al., 2023); low self-efficacy is not a hurdle for personal protective measures (Beckmann et al., 2021), but high self-efficacy increases adaptation intentions (Van Valkengoed et al., 2023). |
| | Response efficacy, i.e., perceived effectiveness of having the desired result through actions | Those who believe individual adaptation can reduce heat stress, take more effective protective measures, and reduce health impact (Heidenreich & Thieken, 2024; McLoughlin et al., 2023). |
| | Risk appraisal, i.e., perceived severity of a threatening event | The perceived probability of the occurrence of heat stress influences people's way of adaptation (Heidenreich & Thieken, 2024). |
| | Aspirations and future making: A desire to achieve something to combat extreme events | Desire for improved living conditions leads to infrastructure development, e.g., cool and green roofs help people to achieve thermal comfort (Schünemann et al., 2024; Wang et al., 2022). |
| Resources | Level of income | Low-income people have fewer resources, capacity, and knowledge to adapt (Berger et al., 2022; Hota & Behera, 2014). |
| | Level of education | Individuals who have completed at least five years of schooling prefer to reduce and reschedule work hours during heat waves (Hota & Behera, 2014). |
| | Knowledge | Knowledge about heat risks through prior experiences and personal learning enhance protective behavior (McLoughlin et al., 2023; Esplin et al., 2019). |
| | Intergenerational learning as intellectual capital | Individuals learn to drink more liquids, cover their heads, wet curtains and textiles from their previous generations (Berger et al., 2022); |
| Sense of place and ownership | Attachment to the place | Land ownership and the surrounding environment create identity and attachment that influence protective behavior, while landless are not likely to take pro-active measures to heat stress (Peng et al., 2020; Esplin et al., 2019; Hota & Behera, 2014) |
| | Sense of ownership (i.e., feelings of belongingness) | People feel responsible for taking measures to adapt to heat stress (Heidenreich & Thieken, 2024) |
| **Community Agency** | | |
| Social capital and community cohesion | Social contact | Calling social contacts when feeling sick due to heat stress ( Guardaro et al., 2022; Watkins et al., 2021); getting helpful information from social contacts (Guardaro et al., 2020); going to a cooler house belonging to family and friends ( Guardaro et al., 2022). |
| | Connections to local community leaders | Community leaders support community members to enhance their adaptive capacity (Guardaro et al., 2022). |
| Common-pool resources and community institutions | Green spaces (e.g., parks) | Urban green spaces create a cooling environment for the surrounding community during extreme heat (Sousa-Silva & Zanocco, 2024). |
| | Water resources | Lakes and ponds keep the living environment cooler during excessive heat (Fung and Jim, 2020). |
| | Community institutions (e.g., clubs, associations) | Clubs or associations take initiatives to support the vulnerable during emergencies (Guardaro et al., 2022), plant trees in the community (Tambo & Abdoulaye, 2013); community members take micro-credit loans from savings associations to invest in less heat-exposed livelihoods (Masuda et al., 2024). |
| Access to key facilities and services | Access to adequate housing | People rest after working or when tired and sleep mainly in cooler places during hot summers (Taylor et al., 2023; Hota & Behera, 2014) |
| | Access to water supply | Water is essential to hydrate individuals during heat stress ( Alizadeh et al., 2022; Hota & Behera, 2014). |
| | Access to electricity supply | Electricity is essential for using electric adaptation accessories (Alizadeh et al., 2022; Hota & Behera, 2014). |
| **Collective Facilitation and Adaptation** | | |
| Effective policies and measures that prevent or significantly reduce the consequences of extreme events | Deliberate plans and actions to promote heat stress adaptation | Cooling-related policies e.g., subsidizing air conditioners, expanding urban greenery (Gabbe et al., 2023; Zanocco & Sousa-Silva, 2023; Adnan et al., 2022; Wong et al., 2021), plans of improving heat warning, response and health plan, and incentivizing uses of cooling materials (Bolleter et al., 2022; Turek-Hankins et al., 2021; Mees et al., 2014a). |

(*continued on next page*)

**Table 1** (*continued*)

| Conditions | Indicators | Examples related to heat stress as reported in the literature |
|---|---|---|
| | Implementation of adaptation measures that curb heat stress | Dissemination of heat prevention information, activation of a general hotline and emergency services (Turek-Hankins et al., 2021; Martinez-Solanas & Basagana, 2019), increasing urban green spaces (Adnan et al., 2022), opening of cooling centers ( Turek-Hankins et al., 2021; Mees et al., 2014a), enhancement of early warning system (Otto & Thieken, 2024; Degirmenci et al., 2021). |
| Just policies and measures that consider vulnerable and marginalized populations | Recognitional justice: Recognition of differential vulnerabilities and proper corrective actions<br>Procedural justice: Inclusion of the voice of vulnerable groups<br>Distributional justice: Proper distribution of cost and benefits, putting the most vulnerable first in terms of benefit distribution | Investing in underprivileged neighborhoods and green spaces, mainly those without permanent homes (Juhola et al., 2022).<br>Inclusion of marginalized groups in the plan of urban gardening (Juhola et al., 2022).<br>Cooling infrastructures in low-income neighborhoods decrease the vulnerabilities of elderly and vulnerable people ( Juhola et al., 2022). |

In addition to social networks, communities have *common resources,* including natural (e.g., parks, lakes, ponds, community gardens etc.) and infrastructural (e.g., schools, mosques, temples, clubs, associations, etc.) resources. These two types of resources are the natural and physical capitals of the LR concept (Department for International Development, 2001). Ostrom (1992) advanced the idea of viable common-pool resources and institutions, challenging the conventional knowledge of common-pool resources management by introducing eight principles based on institutional analysis of shared resources management without external regulation. Local knowledge, social capital, and collective actions are important in common-pool resources management, denoting the strength of communities (Ostrom, 2022). People depend on common-pool resources for their livelihood, for instance, communities surrounded by the Sundarbans in Bangladesh and India collect wood or catch fish (Castro & Sen, 2022). During extreme events like drought, the community collectively manages resources such as drinking water (ibid). Common institutions, for instance, schools, colleges, and clubs are used as shelters for the victims during extreme events. Such multipurpose usage of buildings is common in Bangladesh, particularly in disaster-prone areas (Haider & Ahmed, 2014).

Communities also have paid shared resources and infrastructures essential for their living. Here it is instructive to bring in the *accessibility* concept that focuses on the availability of opportunities, services, and facilities to diverse people, for instance, those of different ages, incomes, genders, and disabilities (Elias, 2020). Accessibility is closely linked to the affordability of providing basic services of water, sanitation, electricity, health care, and housing at low-cost to low-income communities (ibid). Low-income communities in many cities in the Global South rent their homes informally without any legal tenure (Haque, 2021). Consequently, they struggle to acquire public services, including water, sanitation, drainage, and electricity, which exacerbates the difficulties faced during extreme events, such as urban floods (ibid). Access to such facilities and services is linked to the physical capital of infrastructures (Department for International Development, 2001).

The theories and concepts described above – social capital, common-pool resources, and access to key facilities – determine the conditions of community agency, i.e., the ability of the community to support its members to adapt to heat stress (see Table 1).

### *2.3. Collective facilitation and adaptation*

The collective level refers to actions beyond the individual and community level, where government organizations, NGOs, civil societies, and CBOs develop policies and implement measures to support everyone's adaptation (Hainz et al., 2016). Here, individual and community agency represent the scales at which adaptation can be stimulated through the aid of collective facilitation and adaptation. Thus, community agency involves collective initiatives but is distinct from the processes of collective facilitation and adaptation. While community agency refers to the level and capacity of adaptative behavior within the community, collective facilitation and adaptation require external initiatives (Hainz et al., 2016; Newman & Dale, 2005). Policy development for climate change adaptation is inherently complex due to various challenges such as uncertainty, spatial diversity, controversy, and social complexity (Mees et al., 2014b). These challenges do not just hinder policy effectiveness since they are overlooked; rather, they highlight the need for interdisciplinary approaches, and adaptive governance mechanisms that can solve these complex issues known as wicked problems. Without such approaches, policies would become fragmented, reactive, or misaligned with local needs (Termeer et al., 2017; Termeer et al., 2019; Goniewicz et al., 2024). Therefore, addressing these challenges requires not just recognition but the capacity to integrate diverse knowledge systems, stakeholder perspectives, and flexible policy instruments to enhance climate change adaptation (Huitema et al., 2016; Khatibi et al., 2021). Effectiveness is a key integrative criterion for evaluating environmental governance (Adger et al., 2003). It is about achieving the predetermined goals of a policy, or solving problems that the policy addresses (Young, 2011). For our purposes, *effective* policy plans and measures mitigate the problem of climate change by substantially reducing the negative impacts. Effective governance thus aims to secure sufficient adaptation action by governments and NGOs (Mees et al., 2012). For instance, Bangladesh has an effective cyclone preparedness plan that the government executes through disseminating early warnings and supporting vulnerable people, significantly reducing fatalities (Roy et al., 2015). Such collective-level initiatives support individual and community agencies to adapt to extreme events.

In addition to effectiveness, it is crucial that *justice* is ensured by collective-level policies and measures, as climate change impacts everyone differently, resulting in differential vulnerabilities (Amorim-Maia et al., 2022). In turn, these differential vulnerabilities often

exacerbate existing societal inequalities (Cappelli, 2023; Thomas et al., 2019). Here we incorporate the concept of climate justice (CJ) to evaluate the adaptation policies and measures; this has three dimensions to consider (Juhola et al., 2022; Schlosberg, 2004). Firstly, the unequal distribution of measures can cause differential vulnerability, for instance, flood protection measures taken by upstream communities can increase the vulnerability of those downstream (Eriksen et al., 2021). These protective measures are associated with unequal sharing of burdens and benefits that may occur on different scales (Colenbrander et al., 2018). The concept of distributional justice helps to understand how costs and benefits associated with climate risks are distributed among various social groups (Juhola et al., 2022). Hence, ensuring distributional justice requires both climate risk estimation and an appraisal of risk distribution among the relevant social groups (Fiack et al., 2021). Distributional justice is intricately linked to equity (DellaValle et al., 2023); it is achieved when resources and opportunities are distributed equitably, such that the most vulnerable groups, including pregnant women, children, older adults, chronic patients, and low-income people are able to benefit (Chu & Cannon, 2021; Huang et al., 2024; Meade et al., 2024b). Secondly, it is vital to *acknowledge* the diverse impacts and requirements of various vulnerable social groups in the effort to minimize climate risks (Fitzgibbons & Mitchell, 2019). The concept of recognitional justice draws attention to the essential equal rights of vulnerable groups (Newell et al., 2021). A multitude of historical, socio-economic, and other forces lead to already vulnerable people typically bearing the brunt of climate risks. Recognitional justice entails acknowledging the impact of social structure on underprivileged people and recognizing the needs of the most vulnerable groups (Juhola et al., 2022). In developing countries, low-income communities are often unrecognized and consequently precluded from access to government facilities and services, making them more vulnerable to extreme events (Haque, 2021). Thirdly, participation of marginalized people is essential to raise their voice and to include them in planning and decision-making. Decision-making processes are just and legitimate when the policy makers follow inclusive, participatory approaches (Mundaca et al., 2018). Procedural justice is the representation of all affected groups in planning processes and adequate consideration of their ideas (Juhola et al., 2022).

Altogether, the aforementioned concepts of efficacy and climate justice in interventions by governments and NGOs represent the collective conditions for EoA. Effective policies and measures prevent or significantly reduce consequences of extreme events, while just policies and measures consider the needs and contributions of vulnerable and marginalized population groups. Institutional action that satisfies these principles constitutes the collective level of EoA, which informs individual and community level adaptations to heat

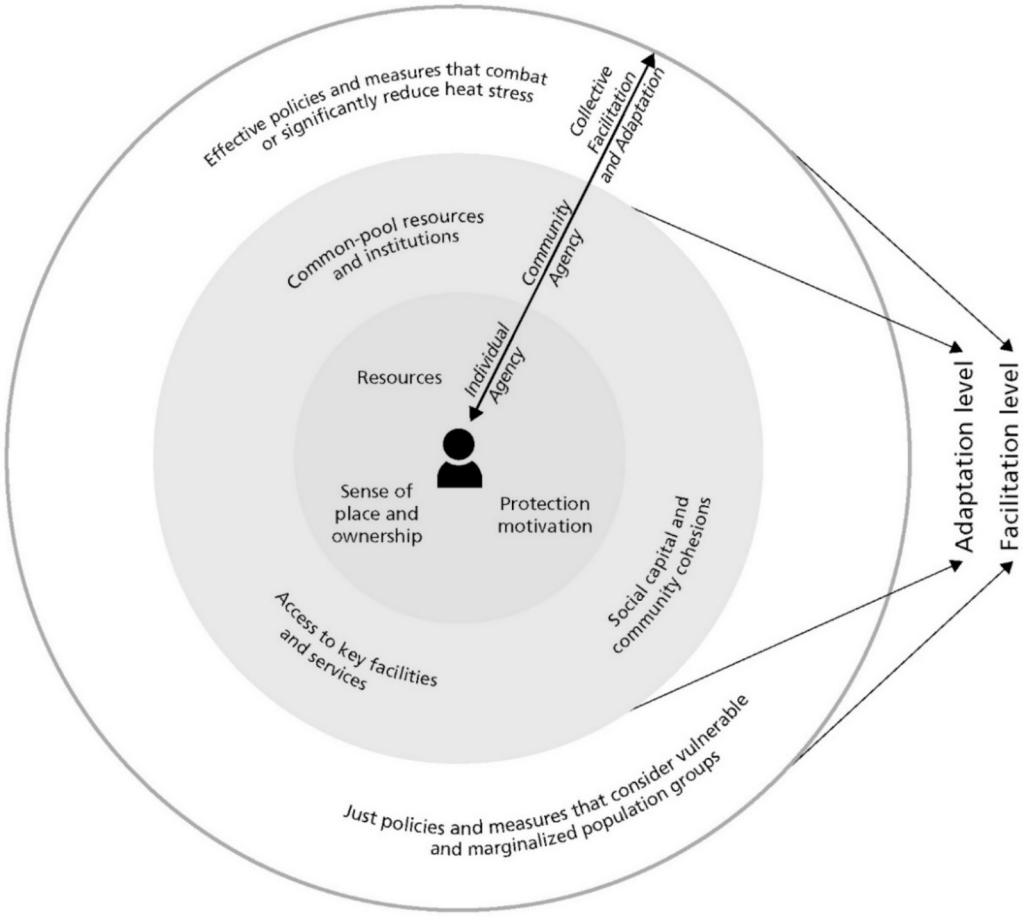


**Fig. 1.** Proposed integrated conceptual framework of EoA (.
Source: Authors' illustration)

stress.

### 2.4. "Everyone's Adaptation" as a novel conceptual framework

EoA represents an ideal adaptation scenario wherein conditions at multiple levels are met to enable each person or household to adapt to current and future threats of climate change through incremental or fundamental modifications of their way of living. The framework is presented in Fig. 1. Here, EoA lies at the nano-level, surrounded by the three distinct levels of conditions (i.e., individual or households— micro-level; community— meso-level; and collective governance— macro-level). Thus, EoA depends on eight independent variables spread over three integrated levels. These conditions, including material and immaterial resources, together determine everyone's adaptation.

With EoA, we mean the act of everyone— all ages, genders, races, socioeconomic and cultural backgrounds— adapting to current and future climate risks through incremental or fundamental modifications in their way of living if they:

i) are willing, able, and feel responsible to make changes in their livelihoods (individual agency)
ii) have access to and support from resources, networks, and facilities from the communities in which they live (community agency)
iii) are supported through effective and fair policies and measures by governments, NGOs and CBOs that consider especially vulnerable and marginalized people (collective facilitation and adaptation).

Here, individual and community agency, respectively, represent the adaptation level, while collective facilitation and adaptation corresponds to the facilitation level (Fig. 1). Tait & Hanna (2015) describe personal and societal adaptation to climate change as actions within the realms of either physiological or cultural adaptation. Physiological adaptation involves physical adjustment to increased temperatures, while cultural adaptation refers to behavioral and technological changes. Navas-Martín et al. (2024) extend this framework by introducing the political adaptation domain, which operates at the collective-level where governments, NGOs, and other stakeholders develop policies and implement adaptation measures. A range of morphological and functional adjustments in physiological adaptation that enable individuals to tolerate heat stress include enhanced sweating efficiency, cardiovascular regulation, and cellular adaptations (Taylor, 2014). However, the extent and time course of these adaptations vary depending on individual variability such as age, pre-existing health conditions, and exposure history. That said some adaptations occur within a week, others may take much longer or never fully develop in certain populations due to biological and environmental constraints (Tyler & Notley, 2024). Moreover, heat adaptation is not only determined by physiological capacity but also emerges from complex interactions between biological systems and social determinants of health and further shaped by external environmental factors, such as high temperatures and humidity, which can limit the body's heat adaptive capacity, increasing health risks (Sturmberg et al., 2019). Vulnerable groups such as pregnant women, children, older adults, chronic patients, and low-income people having lack of access to cooling measures, are particularly at risk because their responses may be insufficient to adapt to heat stress (Huang et al., 2024; Meade et al., 2024b). Our framework considers physiological conditions as a given context, recognizing that they are inherent to each individual and vary from person to person. It focuses on the conditions that matter for better adaptation to heat stress.

The proposed EoA framework aims to explore and explain individual adaptation, particularly how, to what extent, and why everyone adapts to heat stress. We argue that our EoA framework is a more inclusive and comprehensive approach to understanding adaptation. Most empirical studies represent household-level adaptation by interviewing a single household member, typically the household head; however, this does not represent individuals' way of living, particularly since in many patriarchal societies, male household heads are the only earning members. Our proposed EoA differs from other conceptual frameworks in that, besides integrating the three levels, it does not elide individual and household adaptation. Adaptation varies between male and female members, age groups, earning and non-earning members, et cetera. The proposed EoA framework is also open to considering intergenerational learning, where we want to explore the adaptation of heat stress across different generations.

## 3. Operationalization of EoA framework in the context of heat stress

We follow two significant steps to operationalize the framework in the context of heat stress adaptation. Firstly, in Table 1 we present eight conditions of the EoA framework in three levels, i.e., individual (three conditions), community (three conditions), and collective (two conditions). Secondly, we propose relevant indicators for each condition in the context of heat stress to explore how and to what extent those conditions influence everyone's adaptation, particularly by enhancing or constraining their adaptation practices. In addition, we formulate eight propositions for these eight conditions, respectively. Reviewing the current scholarship related to heat stress, we present here how different conditions at each level influences everyone's adaptation to heat stress.

### 3.1. Propositions related to individual agency

Personal experiences of heat-related health issues play a crucial role in shaping individuals' proactive and reactive responses to extreme heat events (Heidenreich & Thieken, 2024; Esplin et al., 2019). This perception of risk and beliefs in one's own ability to cope (i.e., self-efficacy) determines the likelihood of engaging in protective behaviors (Van Valkengoed et al., 2023). While high self-efficacy enhances individuals' intention to adopt both reactive and proactive measures, low self-efficacy does not necessarily hinder the uptake of protective actions, as individuals may opt for simpler strategies such as seeking shade or staying hydrated (McLoughlin et al., 2023;

Beckmann et al., 2021). Moreover, the perceived effectiveness of a protective measure strongly influences its adoption. Individuals are more inclined to adopt measures they believe to be effective in reducing heat stress and its associated health impacts (McLoughlin et al., 2023). For example, some believe eating fermented rice with water can keep them cool during hot days (Hota & Behera, 2014). Additionally, aspirations for improved quality of life and futures **motivate** individuals to invest in proactive measures that will continue to relieve heat stress in the long term, like installation of cooling furniture, and white (cool) and green roofs (Schünemann et al., 2024; Wang et al., 2022; Eriksen et al., 2007). Overall, this leads to our **proposition-1**: the higher the motivation and perceived efficacy and capacity to protect oneself, the greater the likelihood of individuals acting to adapt to extreme heat events.

Individuals who are willing to take protective measures need the resources to ensure their capacity. Individual **resources** include their education, income, knowledge, learning potential etc. Education positively influences an individual's heat stress adaptation (Monsalve & Watsa, 2020; Hota & Behera, 2014). For instance, higher-educated individuals reduce/reschedule working hours during heat waves based on their previous experiences and perceived risk (McLoughlin et al., 2023; Esplin et al., 2019). Higher education also contributes to income-generating activities that limit heat exposure. Evidently, individuals with higher income and higher social status avoid working during heat waves, reflecting and reinforcing their self-efficacy and ability to take action, while low-income and lower socioeconomic class people tend to work unless they become sick (Berger et al., 2022; Hota & Behera, 2014). Osberghaus & Abeling (2022) found a significant association between household income and adopting technologies to relieve heat stress; that is, low-income individuals cut their food expenses to cover the increasing electricity bill, further endangering their living standard and bodily resilience.

In contrast, higher-income people's food expenses remain unaffected by increasing energy expenses (Doremus et al., 2022). Low-income people perceive a greater risk from heat stress because they cannot afford the increased prices related to energy and other livelihood costs. When individuals have adequate finances, they can buy electric fans and pay their electric bill, helping them survive scorching summers (Yazar et al., 2022). However, the effectiveness of fans as a heat adaptation measure remains debated. Studies suggest that fans may be beneficial at lower temperatures but could increase body heat gain when temperatures exceed 35 °C, as they circulate hot air rather than providing cooling (Meade et al., 2024a; Cornwall, 2024). World Health Organization also recommended using fans when the temperature is only below 35 °C and for consecutive 31 hot weather days (Parsons et al., 2023; Morris et al., 2021). This creates a challenge for healthcare agencies and policymakers in providing consistent guidance, especially in low-income communities where fans are commonly used. The lack of clear evidence on the effectiveness of various adaptation strategies, including fans, highlights the need for more context-specific research to inform both individual adaptation decisions and policy recommendations.

Knowledge is important for taking protective actions. It is also related to risk perception, as people attune their perception from previous experiences of dealing with heat stress, enhancing appropriate protective behavior (McLoughlin et al., 2023; Esplin et al., 2019). Individuals also adapt to heat stress through intergenerational learning, for instance, they learn from the experiences of previous generations to drink more water, consume buttermilk, cover their heads under direct sunlight, and wet their household curtains and other textiles (Berger et al., 2022). People also keep the water in mud pitchers, which is the traditional way of cooling water (Gaikwad, 2023; Kavin., 2023); porous earthen pots full of water also act as natural air-conditioning (Henriques, 2019). Such traditional techniques inherited from previous generations enhances their current heat adaptation. Hence, our **proposition-2** is that the greater the individual resources (of income, education, and knowledge), the more able each person is to adapt to extreme heat.

Vulnerability to heat stress is exacerbated by a lack of agency and resources, particularly among groups that cannot limit their exposure. Incarcerated individuals, outdoor workers, especially informal and low-income workers and those living with lack of cooling technologies face heightened risks due to prolonged heat exposure and limited adaptation options (Brunn et al., 2025; Meade et al., 2024b). These populations often lack financial resources or institutional support to implement protective strategies, making them particularly susceptible to heat-related health risks. As Meade et al. (2024b) highlight, individuals with limited resources to reduce heat exposure whether due to occupational constraints, inadequate housing, or physiological vulnerabilities, experience disproportionate morbidity and mortality during extreme heat events. Addressing these disparities requires targeted interventions that integrate physiological, behavioral, and policy-driven approaches to enhance heat resilience in vulnerable communities.

Heat stress changes the surrounding environment and impacts individuals' physical and mental health and wellbeing, which may influence emotional attachment to a place, i.e., **sense of place** (Willox et al., 2012). For instance, cutting down trees for new infrastructure in the neighborhood increases the locals' unhappiness, as they usually congregate in shaded areas during hot weather (Middel et al., 2016). People who have their own land feel more attached to their place of residence and take pro-active measures to protect themselves from the heat stress, while such behavior is less common in landless people who live in rented housing (Rony & Alamgir, 2023; Peng et al., 2020; Willox et al., 2012; Esplin et al., 2019; Hota & Behera, 2014). For example, people can plant trees on their own land to cool the hot environment, creating a more pleasant environment that improves physical and mental health (Turner-Skoff and Cavender, 2019). Such actions can further reinforce their sense of place: they can grow resources that enhance their economic condition like fruit and fuelwood (Fransen, 2023), and consequently, are less likely to harbor intentions to migrate (Mallick, 2023). Likewise, when individuals have **ownership** of their own risks at place, they feel responsible for taking adaptive measures to protect themselves from heat stress. Therefore, our **proposition-3** is that the greater the sense of place and ownership towards the affected locality, the more responsible individuals feel to adapt to extreme heat.

### *3.2. Propositions related to community agency*

Social networks make individuals aware of the consequences of extreme heat that lead to an effective change in their normative behavior and support them during health emergencies (Mondal et al., 2024). Nevertheless, independent older adults have been found

to dislike the paternalistic attitude of their social contacts, feeling that their freedom is disrupted when friends and family urge them to drink water, wear light clothes, or stay home during extreme heat (Mees et al., 2014a; Wolf et al., 2010). Still, Guardaro et al. (2022) claim that individuals rely on social contacts, mainly their relatives, to adapt to heat stress during emergencies. Individuals also seek support from community leaders to enhance their adaptive capacity. People exposed to heat may stay in a cooler house belonging to a relative during extreme heat (ibid). Individuals who live in close-knit neighborhoods tend not to consider their livelihoods at risk from extreme heat as they trust in the community to help them overcome adverse situations (Yazar et al., 2022). Furthermore, the mental and physical health challenges produced by extreme heat can be shared with neighbors, which may reduce mental stress and increase **community cohesion** (ibid). Hence, our **proposition-4** is that the more connected people are to their social network, the better everyone can adapt.

Community cohesion is also important as individuals share **common-pool resources and community institutions** with their neighbors, like shaded green spaces, water sources, and other social resources, like membership in cooperatives, clubs, associations, local organizations, etc. (Guardaro et al., 2022). Neighborhood green spaces create a cooling environment during extreme heat that encourages people to stay together during hot days (Sousa-Silva & Zanocco, 2024). Lakes and ponds also provide cooler environments during daytime (Fung and Jim, 2020). Additionally, vulnerable individuals depend highly on their access to resources, particularly from services initiated by community or religious organizations for heat stress adaptation (Guardaro et al., 2022; Watkins et al., 2021). People can take credit from community savings associations to invest in transitioning to less heat-exposed livelihoods, for instance, home-based small businesses (Masuda et al., 2024; Miller, 2023). However, debt arising from such credit may cause further insecurities in maintaining basic household needs and thereby impact adaptation strategies at the individual level. This leads to our **proposition-5** that the more common resources and institutions the community has, the better everyone can adapt.

Correspondingly, **access to key facilities and services**, like water supply, electricity connection, and insulated housing, influences heat stress adaptation (Taylor et al., 2023; Alizadeh et al., 2022). Lack of access to these facilities worsens quality of life during episodes of extreme heat. Access to water supply becomes scarcer in many places during summer, negatively impacting individuals' heat stress adaptation (Raana, 2024). Adequate housing where proper insulation and cooling technologies enable individuals need to rest and sleep at night is an integral part of adaptation (Taylor et al., 2023). According to the World Bank (2022) electricity access in low-income countries remained significantly below the global average, with 52 % of the world's unserved population residing in these nations as of 2020. This trend underscores persistent energy inequalities and the challenges in ensuring a reliable electricity supply. Without a reliable electrical supply for cooling technologies, people sit outside in the shade of trees or buildings as their houses become more heated through the day (Berger et al., 2022). Hence, our **proposition-6** is that the greater the access to key community resources and services, the better everyone can adapt.

### *3.3. Propositions related to collective facilitation and adaptation*

**Effective policies and measures that prevent or significantly reduce the consequences of extreme events** are important for individual heat stress adaptation. Governance initiatives, including collective policies and practices, influence everyone's heat stress adaptation. Governments can implement plans to improve heat stress-related early warning systems and health prevention and response plans (Otto & Thieken, 2024; Turek-Hankins et al., 2021). An early warning system developed by the central government and implemented by the local government also stimulates community and individual-level adaptation by alerting people to daily actions before upcoming heat waves (Heidenreich & Thieken, 2024; Degirmenci et al., 2021). Governments often disseminate preventive information to the public, particularly those belonging to high-risk groups, when extreme heat is forecasted; and activate general hotlines and special emergency services (Turek-Hankins et al., 2021; Martinez-Solanas & Basagana, 2019). Governments can also incentivize or legislate the use of heat-absorbing construction materials, including high-albedo or green roofs (Bolleter et al., 2022; Turek-Hankins et al., 2021; Mees et al., 2014a). They can formulate policies to increase urban green infrastructure including street trees, parks, and urban forests which reduces heat stress, and subsidize air conditioners and other cooling equipment (Gabbe et al., 2023; Zanocco & Sousa-Silva, 2023; Adnan et al., 2022; Wong et al., 2021). They can open cooling centers or use public buildings as cooling centers (Islam, 2023; Turek-Hankins ret al., 2021; Mees et al., 2014a). However, such initiatives also have negative consequences, for instance, if the local government creates green spaces without proper planning consultation, and far from areas where vulnerable people live, exacerbating existing inequalities (Venter et al., 2023). Thus, our **proposition-7** is that governments and NGOs/CBOs should adopt heat adaptation policies that are tailored to local circumstances, effectively implemented, and coherently coordinated across institutions to enhance protection against heat stress.

The policies and measures governments, NGOs, and CBOs take must also be just. **Just policies and measures that consider vulnerable and marginalized populations** enhance individual adaptation to heat stress (Mees et al., 2014a). Vulnerable groups must be identified to determine which people are the most susceptible to heat stress (Yang et al., 2021). Juhola et al. (2022) claim cooling infrastructures in low-income neighborhoods decrease the heat vulnerabilities of elderly and vulnerable people. Fair consideration of all social groups is essential, and the acknowledgement of their needs related to heat stress adaptation (Yazar & York, 2022). The most vulnerable people, who often constitute racialized groups, must not be ignored or displaced by government development projects ostensibly undertaken for urban improvement (ibid). For example, governments can invest in increasing green spaces for underprivileged neighborhoods, mainly for those who are not landowning to enhance their heat stress adaptation (Juhola et al., 2022). In addition, the inclusion of the voices of vulnerable groups in policymaking is essential. Such representation in planning is scarce at present beyond smaller scale ventures like urban gardening. It is important to put the most vulnerable first regarding benefit distribution (Paavola & Adger, 2006). This leads to our **proposition-8**: just policies and measures that prioritize and address the needs of vulnerable and marginalized populations significantly enhance their adaptation to heat stress, particularly when these groups are

actively included in the policymaking process.

## 4. Applicability of EoA

The scope of employing the EoA framework in the context of climate change adaptation is broad and multifaceted, as it offers a holistic understanding of how individuals across various demographics and contexts adapt to various forms of climate stress. Our operationalization of EoA with respect to heat stress provides insights into the underlying conditions that enable or hinder adaptation to heat stress. By accounting for the interplay of conditions at multiple levels, policymakers at (local) governments and NGOs can better tailor interventions to address place- and group-specific needs and promote equitable adaptation, informing the development of inclusive and effective climate change adaptation policies and measures. This holistic perspective encourages collaboration across sectors and disciplines, for instance: (i) by focusing on conditions of individual, community and collective levels; and (ii) by integrating concepts such as LR, PR, PMT, common-pool resources, accessibility, CJ, which promotes inter- and *trans*-disciplinary approaches to adaptation planning and implementation. This long-term perspective is essential for building resilience to ongoing and future climate change impacts. Overall, the inclusive, comprehensive, and integrated approach of EoA holds promise for promoting effective and equitable adaptation to climate change across diverse contexts.

EoA investigates the underlying conditions of everyone's adaptation at all levels. By foregrounding the interplay of an array of diverse, multi-scale factors, the framework emphasizes that accessibility and proper consideration of these interrelated conditions enhance everyone's adaptation; inaccessibility, inequality, or an otherwise partial appraisal of the intricate network of conditions governing the climate risks people face hinders adaptation. In this conceptual paper, we have operationalized the EoA framework for heat stress. We propose this framework can be easily adapted to other climate change events apart from heat stress, such as flooding, cyclones, drought, et cetera in different Global South and North geographical contexts. The conditions we have discussed that determine EoA, we assume to be generic; however, the indicators may vary based on the spatial locations and hazards at hand, influencing the adaptation process differently in various places. Overall, we posit that the EoA framework has a significant implication for developing adaptation policies to enhance (or edify) individual-level adaptation. We argue that there is a gap between current adaptation policies and the real needs of everyone, especially the most vulnerable. The EoA framework advocates improved adaptation knowledge by identifying the conditions everyone requires to adapt to climate change. To thoroughly understand 'everyone's adaptation,' studying conditions at all levels that comprise the total adaptation process is essential.

An analysis of EoA requires considering the complexity of adaptation by examining how different combinations of conditions contribute to or inhibit adaptation across cases, where qualitative, quantitative, and even mixed methods can be employed. There may be synergies between traditional and scientific knowledge that can identify effective climate change adaptation through community initiatives (Makondo & Thomas, 2018). There could be also trade-offs between short-term solutions and long-term sustainability, for instance, adopting energy-intensive air-conditioners; communities must balance the costs and benefits of these kind of strategies (Kondo et al., 2021). In cases where the number of observations (N) is relatively low, traditional statistical analyses may lack the statistical power to detect meaningful relationships in the context of individual or small-group adaptation. QCA is well-suited for such "small-N" problems because it emphasizes qualitative comparisons rather than relying solely on large sample sizes. The comparative lens of QCA allows for insights into the diversity of adaptive responses and the factors contributing to adaptation across various contexts.

This framework provides a structured approach for both researchers and policymakers to understand and enhance individual heat stress adaptation strategies. Researchers can use this EoA framework to develop indicators that measure various aspects of climate change adaptation, such as individual and community resources, social capital, and collective capacities. Moreover, the flexible yet comprehensive outline offered by the framework provides a basis for comparing everyone's adaptation across regions and communities. For environmental epidemiologists, EoA offers a systematic way to categorize and analyze different adaptation mechanisms at individual, community, and policy levels. For instance, in studying heat-related mortality, researchers can use the framework to differentiate between behavioral responses (e.g., hydration practices, use of cooling strategies), community-based interventions (e.g., neighborhood cooling places, social support networks), and policy-driven adaptations (e.g., heat action plans, subsidy programs for cooling technologies). By incorporating these dimensions, the framework supports interdisciplinary research that connects physiological vulnerability with broader environmental and social determinants. For policymakers, the framework highlights the interaction between individual agency, collective facilitation, and institutional support, helping to design more comprehensive heat adaptation policies. For instance, policymakers can leverage the framework to design policies that enhance adaptation, such as improving access to natural resources, investing in cooling infrastructure, and strengthening local governance. It can guide the development of multi-level interventions, such as financial assistance programs for vulnerable populations, infrastructure improvements like expanded green spaces, and public awareness campaigns promoting heat risk reduction behaviors. By structuring adaptation strategies across multiple levels, the framework ensures that policies address both immediate and long-term challenges of heat stress and by bridging research and policy needs, this framework serves as a practical tool for designing targeted interventions that enhance heat resilience in diverse populations. For vulnerable groups, the EoA framework helps identify targeted interventions, like promoting alternative livelihoods or improving access to heat alerts. It also emphasizes community-based approaches, such as participatory natural resource management and community savings groups, to support long-term adaptation. Similarly, differences in EoA can also be explored by considering variations in age, gender, educational backgrounds, health issues, and socioeconomic status. Finally, the proposed EoA framework considers both current coping mechanisms and planned adaptation strategies for future climate change. Notably, it accounts for incremental alterations that denote the small, significant, and repetitive actions in daily life based on aspirations and priorities, which explain the way of living at the individual level and may be overlooked in top-down approaches. The EoA framework considers

individual, community, and collective conditions that jointly influence everyone's adaptation differently. The integration of these diverse conditions makes the EoA framework comprehensive, inclusive, and novel.

## 5. Conclusion

The EoA framework focuses on practical strategies for adaptation that resonate with a broad audience and therefore stands a better chance of being embraced and utilized. The key innovative aspects of our proposed EoA approach are:

(i) comprehensiveness and multi-level integration of the conditions across individual, community, and collective levels, offering a scientific approach that reveals how different levels of adaptation are interconnected and impact overall resilience to, in this case, heat stress.
(ii) the incorporation of intergenerational learning and empirical investigation of how past and current generations adapt to climate change, an adaptable and underexplored dimension of adaptation that can foster innovative and participatory approaches to climate resilience, and
(iii) global applicability, with regard for regional sensitivity, as the EoA framework is designed to be relevant for both the global North and South.

The EoA framework acknowledges and addresses region-specific conditions, such as informality in governance, ensuring broader applicability and effectiveness. In comparison, the heat stress adaptation framework proposed by Navas-Martín et al. (2024) integrates physiological, cultural, and political factors at both individual and societal levels, but it does not explain how conditions at different levels influence human adaptation. The EoA framework addresses this gap by showing how conditions across various levels interconnect and impact adaptation for everyone. Further, Satterthwaite et al. (2020) raise how many climate adaptation frameworks are developed with a primary focus on conditions and contexts prevalent in the global North, which often do not translate well to the unique challenges faced in the global South. This discrepancy highlights the need for frameworks that are adaptable and sensitive to the specific socio-economic and environmental contexts of different regions. The EoA framework, accordingly, can account that some conditions, like informality affecting governance of basic services, are more significant in the global South than in the global North.

Therefore, the point of departure for further research employing the EoA framework for heat stress would be to investigate conditions of all levels that directly and indirectly influence heat stress adaptation. A key area of investigation will be the role of individual agency and social capital in community-level adaptation, as well as the influence of intergenerational learning on adaptation strategies. This research should examine how past and present generations contribute to and learn from each other, providing a historical perspective on adaptation. Additionally, the integration of governance systems within the EoA framework will facilitate the analysis of how policies and actions affect adaptation at both individual and collective levels. Overall, further research should enhance the EoA framework's inclusivity, equity, and applicability, promoting innovative and participatory approaches to managing climate stress. Our proposed concept EoA, therefore, will represent a shift towards more inclusive, equitable, and participatory approaches to addressing heat stress and other climate-related challenges. By centering the needs and experiences of diverse individuals and related stakeholders tackling heat stress, EoA can foster innovation, collaboration, and resilience-building efforts that help communities thrive in a warming world.

## Funding Sources

This research was supported by Dean's Policy Resources 2023 of the Faculty of Geosciences at Utrecht University, the Netherlands with the grant number WA.148152.1.009.

## CRediT authorship contribution statement

**Zakia Sultana:** Writing – review & editing, Writing – original draft, Visualization, Conceptualization. **Heleen L.P. Mees:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Bishawjit Mallick:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Peter P.J. Driessen:** Writing – review & editing. **Ajay Bailey:** Writing – review & editing.

## 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

Authors are grateful to the Dean's Policy Resources Funding initiative of Utrecht University, the Netherlands for the PhD project "BEAT THE HEAT". Moreover, authors are thankful to Drs. Ton Markus, Cartographer of the Faculty of Geosciences at Utrecht University for his support on editing the figure of the conceptual framework. Furthermore, authors are also thankful to Rupkatha Priodarshini for her copy-editing supports.

## Data availability

Data will be made available on request.

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