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Socio-economic projections in urban climate change adaptation planning: Practices and prospects for just adaptation

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ABSTRACT

Urban climate change adaptation efforts have often been criticized for exacerbating the inequitable impacts of climate change by failing to address the social, economic, and environmental impacts of adaptation. There is an urgent need to incorporate equity and justice concerns in adaptation planning as well as approaches and tools that enable such integration. However, climate justice scholarship to date has largely focused on theoretical questions and there is still a lack of focus on the operational aspects for supporting the implementation of climate justice. In this article, we argue that existing tools already in use in planning practice have the potential to support this aim. In particular, we argue that the integration of socio-economic data into adaptation planning practice could be an avenue for justice-centered urban adaptation. While the potential is clear, how to do this is still underexplored. To shed light on this question, we conduct a systematic review of research on the use of socio-economic projections in urban climate change adaptation planning and decision-making to investigate how these could be used as a tool to ensure just urban adaptation. Grounded in a recognized conceptual framework on urban climate justice, we analyze the evolution of research on socio-economic projections in urban adaptation and evaluate the potential for existing applications to promote climate justice. Through this analysis, we find that while socio-economic projections have not been explicitly linked to justice outcomes in the existing literature, clear potentials exist for these to be used as a tool to promote distributive, procedural, and recognition and restorative justice. Finally, we propose an operational framework for the application of socio-economic projections to promote justice-centered urban adaptation. Applying such a framework to urban adaptation planning can help center justice concerns in larger strategic adaptation planning efforts and enable a new form of more inclusive, data-driven climate governance in cities based on current know-how and existing capacities.

1. Introduction

While climate change is inherently a global challenge, the impacts of a changing climate are not felt equally across world regions, nations, cities, or communities. Climate change disproportionately impacts those who have contributed least to global greenhouse gas emissions and leaves marginalized and minority groups with low adaptive capacity highly exposed to climate hazards (Granberg & Glover, 2021; Hughes & Hoffmann, 2020; Shi, 2021; Shi et al., 2016). Policy and planning efforts have often exacerbated the inequitable impacts of climate change by failing to address social, economic, and environmental consequences of climatic changes (Eriksen et al., 2021). This has often lead to unexpected and unconsidered negative effects, in other words, to maladaptation (Hughes, 2020; Shi et al., 2016).

At an urban scale, the impacts of both climate change and adaptation responses become spatially explicit leading to unique challenges for equity and justice in adaptation planning. Cities have historically been sites of increased inequality and have more recently become hotspots of heightened risk through increases in hazards, exposure and vulnerability in the face of climate change (Dodman et al., 2022). Urban Climate Change Adaptation (CCA) efforts have often also reinforced existing inequalities in cities through their tendency to selectively protect urban spaces and assets that are valued from an economic perspective (Chu & Cannon, 2021; Granberg & Glover, 2021; Steele, Maccallum, Byrne, & Houston, 2012).

There is thus a clear need for consideration of justice at all stages of

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urban adaptation policy and planning practice. It is critical to advance creative, inclusive approaches to planning and governance that challenge drivers of systemic inequity in cities and enhance adaptive capacity for all urban dwellers (Granberg & Glover, 2021; Shi et al., 2016; Steele et al., 2012). However, climate justice scholarship to date has been primarily theoretical and has given limited attention to how to apply equity and justice criteria in CCA planning and policy making (Amorim-Maia, Anguelovski, Chu, & Connolly, 2022; Hughes & Hoffmann, 2020). From a practice point of view, emerging evidence points out how cities struggle to be early adopters of equitable adaptation strategies by normalizing the climate equity rhetoric through adaptation planning procedures (Cannon, Chu, Natekal, & Waaland, 2023).

Here we argue that the integration of future socio-economic data could be one avenue through which to operationalize climate justice in adaptation planning and policy making. While future climate scenarios have become common best practice tools for adaptation planning (Dessai, Lu, & Risbey, 2005), such projections are rarely accompanied by scenarios of future vulnerabilities (Jurgilevich, Räsänen, & Juhola, 2021; Olazabal, Galarraga, Ford, Sainz De Murieta, & Lesnikowski, 2019), i.e., by an understanding of how economy and society evolve and change under climate impacts (and actions) or under other evolving contextual environmental, social or economic conditions. Such a narrow approach to adaptation planning that only considers the future evolution of climate hazards while neglecting the dynamic nature of exposure and vulnerability will inevitably give rise to issues of maladaptation and injustice as such an approach fails to consider evolving local needs (Birkmann et al., 2020; Jurgilevich et al., 2021; van Ruijven et al., 2014).

Socio-economic projections illustrate potential development futures and have the potential to help decision makers visualize who to plan for and how to promote solutions for climate resilient development that not only cope with future climate uncertainty but also respond to evolving socio-economic needs of diverse urban communities. It is widely acknowledged that evidence-based decision making is critical in advancing urban climate action. However, data-driven urban governance has been criticized for its technocratic nature and tendency to favor external economic interests over local needs (Hughes, 2020). While the exercise of projecting potential futures may traditionally be associated with technocratic, quantitative approaches to planning, the core concept of socio-economic projections is much broader. Attempts to counteract the overly technical nature of urban climate action have often employed participatory approaches to planning. However, successful integration of scientific and local or alternative knowledge systems in adaptation planning remains scarce (Olazabal, Chu, Castán Broto, & Patterson, 2021). The application of socio-economic projections to urban adaptation governance could represent a unique opportunity to combine diverse forms of scientific and local knowledge without sacrificing the adoption of more inclusive data-driven decision making. While socio-economic projections have potential to inform both adaptation and mitigation planning and policy making, local demographic growth and local policies in general are main drivers of urban climate vulnerabilities (Viguié, Hallegatte, & Rozenberg, 2014). Rightly, these kinds of data have been historically included in mitigation planning processes, but have not been used in adaptation planning and decision making as often, with important implications for equity and justice (Anguelovski et al., 2016).

It is therefore pertinent to investigate how inclusive applications of socio-economic projections can be used as a tool to bridge the gap between technical, scientific information and local knowledge to realize a new equitable form of data-assisted urban climate governance. After framing the question through a discussion of the three core concepts of our conceptual and analytical framework, we perform a systematic literature review and thematic analysis that seek to investigate two questions: (1) how socio-economic projections are framed as a tool in urban CCA planning, and (2) how they can be used to ensure climate justice, according to scholarly community. Based on the findings, we propose an operational framework for the application of socio-economic projections that can help center justice concerns in larger strategic adaptation planning efforts.

2. Framing the question

We discuss below the three core concepts for the conceptual and analytical framework adopted for this study: (1) socio-economic projections (or scenarios), (2) the urban CCA planning process and (3) theories on urban climate justice.

2.1. What are socio-economic projections and how are they applied?

Socio-economic projections or scenarios have a wide range of definitions and applications but can broadly be understood as models of potential future development trends based on projected socio-economic variables such as population, demography, economic development, and land use. Socio-economic projections can be applied across individual or combined spatial scales. Some define socio-economic scenarios as combinations of quantitative and qualitative information that together characterize possible futures (Kriegler et al., 2012). We take a broader view of socio-economic projections or scenarios as qualitative, quantitative, or spatial projections of potential development futures. This implies that socio-economic projections encompass global, quantitative projections of population or land use change but also includes locally specific scenarios of potential development futures. Likewise, we use the terms ‘projection’ and ‘scenario’ interchangeably.

Several iterations of global socio-economic projections have been produced within the climate change research arena over the past several decades. The Special Report on Emissions Scenarios (SRES) published by the IPCC in 2000 contains early socio-economic projections (Arnell et al., 2004). The shared socio-economic pathways (SSPs) (IIASA, 2018) outline five potential future development pathways in the form of qualitative narratives and quantitative projections on a global, regional, and national scale (IIASA, 2018).

In addition to the SSPs, local socio-economic scenario analysis is increasingly being used in country, city, and sector specific studies on CCA (van Ruijven et al., 2014). Scenarios used at these finer scales are either downscaled from global projections such as the SSPs or are created through bottom-up approaches that focus on a specific local context (Birkmann et al., 2020; 2021; van Ruijven et al., 2014).

2.2. Which are the main elements of the urban climate change adaptation planning process?

Socio-economic projections can be used at different stages of the urban adaptation planning process, with different purposes. In order to enable a discussion of the applicability of socio-economic projections to urban climate change adaptation, it is useful to distinguish key stages of urban adaptation planning and associated actions. Urban planning processes, tools and rules are widely recognized as institutional enablers of climate adaptation action (Carter et al., 2015; Olazabal & Castán Broto, 2022). Urban CCA planning includes deliberate decision making intended to minimize risk and maximize opportunities of climate change (Araos et al., 2016; Füssel, 2007). Urban adaptation planning should then consider questions regarding future climate variability, the impact of future changes on current decision making, and the potential consequences of immediate or postponed action (Füssel, 2007). The urban CCA planning process generally follows several phases (sometimes, in practice, not necessarily sequential) including risk assessment, identification and selection of adaptation options, implementation, and monitoring and evaluation (Climate ADAPT, n.d.). Table 1 details the specific actions that may be taken at each stage of the urban CCA planning process.

Table 1
Stages of the urban climate change adaptation planning process. Adapted from Climate adapt (n.d.), New et al. (2022), and Olazabal and Castán Broto (2022).

Planning Stage	Actions
Preparing the ground for adaptation	● Obtaining political support for adaptation ● Collecting initial information ● Setting up adaptation processes within and beyond the municipality ● Identifying and obtaining human and technical resources and responsible parties ● Identifying and obtaining financing and funding ● Identifying and engaging stakeholders ● Communicating adaptation
Assessing climate change risks and vulnerabilities	● Recognizing past, present, and potential future climate impacts ● Understanding climate projections and future impacts ● Identifying vulnerable urban sectors ● Conducting risk and vulnerability assessments ● Understanding the role of surrounding areas in adaptation ● Identifying main adaptation concerns and identifying general goals and specific objectives for adaptation
Identifying adaptation options	● Creating a catalog of relevant adaptation options ● Screening for relevant examples of good adaptation practices
Assessing and selecting adaptation options	● Choosing an assessment framework for adaptation options ● Conducting an evaluation (e.g., cost-benefit analysis, feasibility, urgency) of adaptation measures ● Prioritizing adaptation options ● Identifying responsible parties for implementation
Implementing adaptation	● Designing an effective/feasible adaptation action/implementation plan ● Financing and leading adaptation process ● Finding examples of adaptation action plans ● Mainstreaming adaptation in urban policies and plans
Adaptation monitoring, evaluation and learning	● Developing the monitoring and evaluation approach ● Defining monitoring and evaluation indicators to measure adaptation progress and adaptation impacts ● Finding examples of adaptation monitoring and/or evaluation indicators ● Using monitoring and evaluation results to enhance the process of adaptation

2.3. A framework for urban climate justice

Theories of urban climate justice can help us to understand the justice implications of each step of the urban CCA planning process. The shift towards a justice-centered view of CCA has been associated with a number of different theories surrounding issues of equity. Urban justice and environmental justice can be understood as key founding concepts that have eventually led to the popularization of the term climate justice (Bulkeley, Carmin, Castán Broto, Edwards, & Fuller, 2013; Granberg & Glover, 2021; Hughes, 2020). The following conceptual framework provides an overview of the three pillars of urban climate justice most often discussed in the literature and is used to understand urban climate justice in this study (see Fig. 1).

For the purposes of our specific study, this framework summarizes theory on urban and environmental justice (Granberg & Glover, 2021; Hughes, 2020; Hughes & Hoffmann, 2020; Reckien et al., 2018; Steele et al., 2012), climate justice and climate just cities (Bulkeley et al., 2013; Dadashpoor & Alvandipour, 2020; Hughes & Hoffmann, 2020; Jurjonas, Seekamp, Rivers, & Cutts, 2020; Mohtat & Khirfan, 2021; Swanson, 2021), climate urbanism (Bulkeley, 2021; Castán Broto & Robin, 2020; Long & Rice, 2018), just adaptation (Malloy & Ashcraft, 2020), just urban transitions (Heffron, 2021; Hughes & Hoffmann, 2020), and the right to the city (Granberg & Glover, 2021; Hughes & Hoffmann, 2020) to define urban climate justice in the context of urban adaptation planning. It will be used to connect socio-economic projections with specific urban adaptation justice outcomes.

3. Data and methods

We perform asystematic review following principles proposed by Berrang-Ford, Pearce, and Ford (2015) to apply this method specifically to adaptation research. The literature search and selection process used is visualized in Fig. 2.

The literature search was conducted in the Web of Science and was limited to results in English as well as to articles or reviews. All other document types were excluded from the analysis. No temporal range or geographical delimitation was specified in the search process. Search terms were selected based on the research objective. In this case, “urban”, “climate change”, “adaptation”, “socio-economic projections”, and “justice” were considered key terms. An iterative process was applied to test different search strings using these key terms as well as synonyms and related terms. During this process, it was found that including terms related to justice and equity in search strings produces irrelevant results due to the lack of literature currently linking justice issues to both urban CCA and socio-economic projections. Therefore, the choice is made to exclude justice from the final search string and instead critically analyze the selected literature on the use of socio-economic projections in urban adaptation planning through the lens of the urban climate justice framework. This critical analysis is presented in Section 4 and assesses the extent to which socio-economic projections are currently proposed as a tool to support climate justice in urban adaptation planning and also how such projections could potentially support justice outcomes in the future. While refining the search string, searches including the term “assessment” as well as those including “social” and “economic” were tested with the intent of broadening the results, however, it was ultimately concluded that the inclusion of these terms led to numerous irrelevant results that did not fit the scope of the study. For example, including these terms yielded many results that did not employ socio-economic projections and therefore these terms were consequently excluded. With these considerations in mind, the following final search string was developed: *(urban* OR “cities” OR “city” OR “municipal”) AND climat* AND adapt* AND (“socioeconomic” OR “socio-economic”) AND (“projection” OR “scenario” OR “pathway”)*.

The search (see Fig. 2) was conducted in the Web of Science Core Collection on February 28th, 2022 and produced 127 results. In the first stage of literature selection, results were filtered for inclusion based on language (English) and document type (article or review), thus limiting the material considered to 117 results. In the second stage of literature selection, results were selected for inclusion based on four inclusion criteria: (1) article is urban scale or discusses urban issues, (2) focus on climate change, (3) focus on adaptation, and (4) article discusses or applies socio-economic projections or scenarios. A review of article titles and abstracts was performed to identify publications in line with these criteria. On this basis, 41 results were selected for inclusion and 76 results were excluded. For a complete list of included and excluded literature, see Supplementary Material 1 (SM1).

Following the final literature selection and critical appraisal, results were analyzed using thematic analysis. The thematic analysis considers both manifest and latent content emerging from the literature. For example, manifest content in the form of phrases such as ‘participatory scenario development’ or ‘SSPs’ was used to understand which type of projections are used in different studies while latent content was used to understand more nuanced discussions surrounding why projections are used and the underlying challenges of applying such projections.

On the basis of the content analysis and to respond to our research questions, results have been grouped into six key themes (see Section 4). These themes enable a comprehensive understanding of why and how

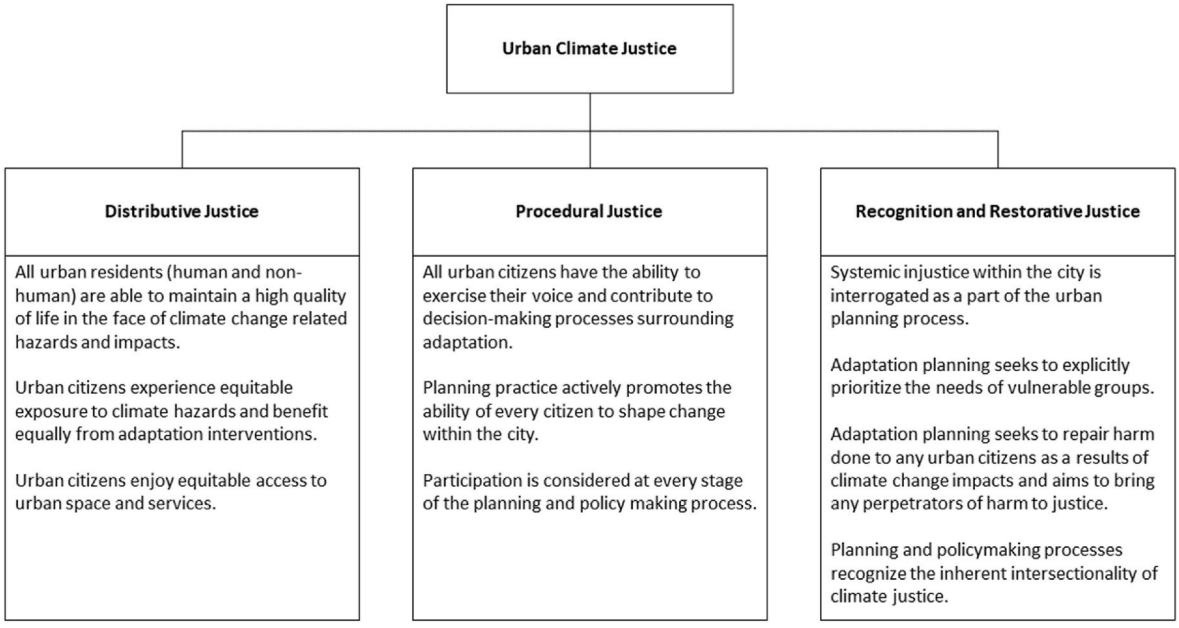

Fig. 1. A conceptual framework for understanding urban climate justice.

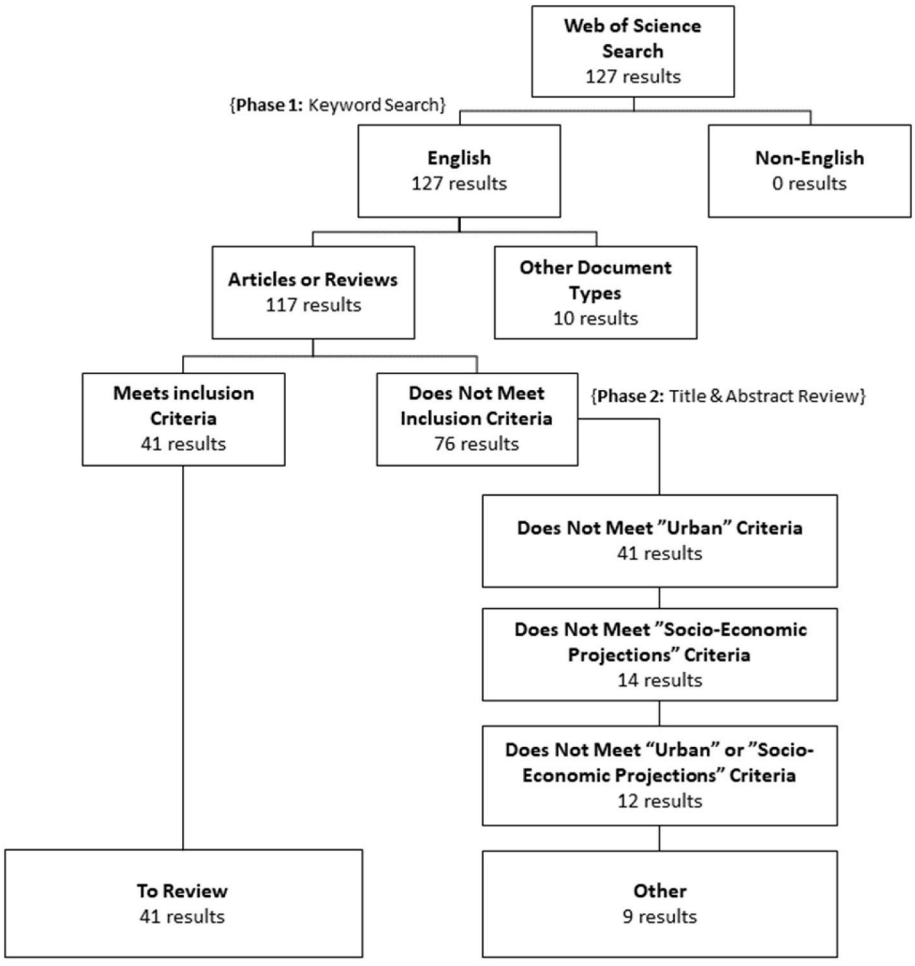

Fig. 2. Literature search and selection process.

socio-economic projections are currently being used in urban adaptation planning. This understanding is then used to critically analyze the potential of socio-economic projections to promote urban climate justice.

4. Results

Research on socio-economic projections in urban CCA first emerged in 2011 and has gained popularity over the past decade. 12 of the 41 publications reviewed were published in 2021, indicating a very recent popularization of the research area. The majority of publications (31) fall within the environmental sciences subject area according to the Web of Science (WoS) categories. Studies primarily take a single hazard approach by focusing on heat (11 publications), flooding (10 publications), or urban water management (9 publications). The geographical coverage of the literature is primarily Asian (14 publications) and European (14 publications).

Our analysis of 41 articles reveals six key themes (the number of associated publications is indicated): (1) justifications for using socio-economic projections in urban climate change adaptation (26 publications), (2) types of socio-economic projections and methods for scenario development in urban adaptation planning (40 publications), (3) use of socio-economic projections throughout the adaptation planning process (41 publications), (4) challenges and limitations of using socio-economic projections in urban adaptation planning (13 publications), (5) recommendations for future use of socio-economic projections in urban adaptation planning (17 publications), and (6) recommendations for future use of socio-economic projections to support urban climate justice (8 publications).

4.1. Justifications for using socio-economic projections in urban climate change adaptation

It is widely regarded that despite future uncertainty, it is essential to make decisions on adaptation today. Scenario-based approaches using socio-economic projections help to facilitate decision making on adaptation in the context of a highly uncertain future (Birkmann et al., 2020; Ciumasu, 2013; Huang et al., 2011; Reimann, Vollstedt, et al., 2021; Rohat et al., 2021; Rohat, Flacke, Dosio, Dao, & van Maarseveen, 2019; Terama, Clarke, Rounsevell, Fronzek, & Carter, 2019).

The goal of scenario analysis is not to reduce future uncertainty but instead to better understand the range of possible futures to make informed decisions on adaptation today (Birkmann et al., 2021; Borris, Leonhardt, Marsalek, Österlund, & Viklander, 2016; Egger & Maurer, 2015; Huang et al., 2011). There is a growing consensus of the need for flexible, low-regret adaptation options that meet current needs, avoid path dependency, and can succeed under a wide range of future climate and socio-economic development conditions (Casal-Campos, Fu, Butler, & Moore, 2015; Li et al., 2017; Manocha & Babovic, 2017; Rohat et al., 2021).

It is especially critical to consider future socio-economic scenarios alongside climate projections to be able to better assess future vulnerability at an urban scale. So far, urban adaptation planning has largely ignored future projections of vulnerability and adaptive capacity (Birkmann et al., 2020; Borris et al., 2016; Meyer et al., 2019; Parandvash & Chang, 2016; Peng & Li, 2021; Reimann, Vollstedt, et al., 2021). When socio-economic development pathways are considered in risk assessments, current socio-economic vulnerability data is often superimposed onto projections of future hazards to determine future risk (Birkmann et al., 2020; Jurgilevich et al., 2021; Rohat, Wilhelmi, et al., 2019).

The failure to consider socio-economic aspects in adaptation planning can lead to poor understanding of future socio-economic development and vulnerability, leading to inappropriate and ineffective adaptation interventions (Birkmann et al., 2020, 2021; Jurgilevich et al., 2021; Meyer et al., 2019; Xu et al., 2021). There is currently limited understanding of how socio-economic changes drive future climate vulnerability, particularly in relation to intersecting, indirect, and cascading effects of such change (Jurgilevich et al., 2021).

Finally, another important justification made by the literature is that the impacts of climate change in the future will be driven not only by shifts in climate but also by socio-economic development changes (Reimann, Jones, Nikoletopoulos, & Vafeidis, 2021; Terama et al., 2019). This is true for a wide range of hazards including heat stress and coastal flood risk (Abadie, 2018; Birkmann et al., 2020; Borris et al., 2016; El-Fadel & Ghanimeh, 2013; Krummenauer, Costa, Prahl, & Kropp, 2021; Park, Thorne, Hashimoto, Lee, & Takahashi, 2021; Wolff, Nikoletopoulos, Hinkel, & Vafeidis, 2020). Some studies even find that future socio-economic variability contributes equally or more to future risk and impact than changes in climate (Borris et al., 2016; Parandvash & Chang, 2016; Parkinson et al., 2016; Rohat, Flacke, et al., 2019; Wolff et al., 2020). Thus, knowing socio-economic futures turns urgent and critical.

4.2. Types of socio-economic projections and methods for scenario development in urban adaptation planning

Socio-economic scenario development and application in urban adaptation planning generally follow two approaches: participatory scenario development or modeling-based scenario development.

4.2.1. Participatory scenario development

Participatory scenario development approaches are often undertaken in response to a lack of local data and are carried out to increase the relevance of scenario development processes, promoting local ownership of adaptation solutions, and building trust among stakeholders (Birkmann et al., 2020; Li et al., 2017; Meyer et al., 2019; Rohat, Wilhelmi, et al., 2019). Out of 41, 13 of the studies analyzed use participatory scenario development approaches as shown in Table 2.

Stakeholder participation is embedded in socio-economic scenario development methodologies in different ways. Some approaches emphasize the co-creation and co-production of knowledge and strive to include stakeholders throughout the entire process (Meyer et al., 2019; Reimann, Vollstedt, et al., 2021). Others, instead, limit the use of stakeholder feedback to the final stages of the scenario development process in order to get local feedback on scenario narratives that have been already partially developed by researchers or to better understand which socio-economic drivers are most important in the local area being studied (Ciumasu, 2013; Jurgilevich et al., 2021; Kamei, Mastrucci, &

Table 2
Urban adaptation literature using participatory scenarios to develop socio-economic projections. Note 1: Some literature uses multiple methods of scenario development and is therefore categorized more than once. Note 2: SSP: Shared Socio-Economic Pathway, SRES: Special Report on Emissions Scenarios. See SM2 for further details.

Type	Methods (#)	Use of SSPs/ SRES (#)	Scenario Output (#)	Sources (#)
Participatory scenario development	Stakeholder workshop (8)	Yes (5) No (3)	Qualitative (8) Quantitative (5) Spatial (2)	(8)
	Stakeholder consultation/ questionnaire (6)	Yes (2) No (4)	Qualitative (2) Quantitative (4) Spatial (3)	(6)
	Participatory mapping (1)	Yes (0) No (1)	Qualitative (1) Quantitative (1) Spatial (1)	(1)

Table 3
Urban adaptation literature using modeling-based scenario development to develop socio-economic projections. Note 1: Some literature uses multiple methods of scenario development and is therefore categorized more than once. Note 2: SSP: Shared Socio-Economic Pathway, SRES: Special Report on Emissions Scenarios. See SM2 for further details.

Type	Methods (#)	Use of SSPs/SRES (#)	Scenario Output (#)	Sources (#)
Modeling-based scenario development	Downscaling (12)	Yes (12) No (0)	Qualitative (1) Quantitative (12) Spatial (9)	(12)
	Predictive/statistical modeling (13)	Yes (4) No (9)	Qualitative (0) Quantitative (13) Spatial (8)	(13)
	Adaptation pathway modeling (2)	Yes (0) No (2)	Qualitative (1) Quantitative (2) Spatial (1)	(2)

van Ruijven, 2021; Rohat, Wilhelmi, et al., 2019). Most participatory approaches focus on including 'expert' stakeholders (Kamei et al., 2021; Meyer et al., 2019; Rohat, Wilhelmi, et al., 2019); however, some also strive to secure broader participation from local citizens (Reimann, Vollstedt, et al., 2021). Stakeholders are generally engaged through workshops, surveys, or questionnaires (Birkmann et al., 2020; Egger & Maurer, 2015; Jurgilevich et al., 2021; Kamei et al., 2021; Li et al., 2017; Meyer et al., 2019).

Scenario outputs from participatory scenario development approaches most often take the form of qualitative narratives describing potential futures (Birkmann et al., 2020, 2021; Ciumasu, 2013; Egger & Maurer, 2015; Jurgilevich et al., 2021; Kamei et al., 2021; Li et al., 2017; Meyer et al., 2019; Reimann, Vollstedt, et al., 2021; Wan, Radhakrishnan, Zevenbergen, & Pathirana, 2020). Some participatory approaches also use qualitative narratives as a starting point for creating quantified and spatialized socio-economic projections (Birkmann et al., 2020, 2021; Egger & Maurer, 2015; Hadipour, Vafaie, & Kerle, 2020; Jurgilevich et al., 2021; Li et al., 2017; Rohat, Wilhelmi, et al., 2019; Ronco et al., 2014; Wan et al., 2020). Li et al. (2017) directly use stakeholder workshops to create quantified socio-economic projections, while Jurgilevich et al. (2021) use participatory mapping to understand spatial patterns of risk under different future scenarios.

While a number of participatory scenario development approaches do not consider the shared socio-economic pathways (SSPs) (Birkmann et al., 2020; Ciumasu, 2013; Egger & Maurer, 2015; Hadipour et al., 2020; Jurgilevich et al., 2021; Ronco et al., 2014; Wan et al., 2020), some studies embed local scenarios in a global context by utilizing the SSPs as boundary conditions for local socio-economic narratives in an attempt to maintain local-global consistency and enable comparison across case studies (Birkmann et al., 2021; Kamei et al., 2021; Li et al., 2017; Meyer et al., 2019; Reimann, Vollstedt, et al., 2021; Rohat, Wilhelmi, et al., 2019).

4.2.2. *Modeling-based scenario development*

Modeling-based scenario development approaches generally take departure in downscaling of larger scale projections (Borris et al., 2016; K. Chen et al., 2017; Dubey, Lal, Kumar, Kumar, & Dvornikov, 2021; El-Fadel & Ghanimeh, 2013; Krummenauer et al., 2021; Park et al., 2021; Parkinson et al., 2016; Peng & Li, 2021; Rohat et al., 2021; Rohat, Flacke, et al., 2019; Terama et al., 2019; Wolff et al., 2020) or predictive modeling approaches that generate a wide range of possible future scenarios. Predictive modeling methodologies are diverse but include stochastic modeling (Abadie, 2018; Hemmati, Mahmoud, Ellingwood, & Crooks, 2021), gravity-based modeling (Reimann, Jones, et al., 2021), and CA-Markov modeling (X. Chen, Zhang, Chen, & Huang, 2021; Xu et al., 2021). Two studies take a slightly different approach by modeling adaptation pathways using mapping or pathway generation approaches (Manocha & Babovic, 2017; Urich & Rauch, 2014). A total of 27 studies use modeling-based approaches as shown in Table 3.

While some modeling-based approaches use SSPs (Borris et al., 2016; K. Chen et al., 2017; X. Chen et al., 2021; Dubey et al., 2021; Krummenauer et al., 2021; Park et al., 2021; Parkinson et al., 2016; Peng & Li, 2021; Reimann, Jones, et al., 2021; Rohat et al., 2021; Rohat, Flacke, et al., 2019; Terama et al., 2019; Wolff et al., 2020; Zhu et al., 2020), others, instead, rely on mathematical calculations of potential future scenarios (Abadie, 2018; Apreda, D'Ambrosio, & di Martino, 2019; Banu, Hu, Guo, Hurst, & Tong, 2014; Casal-Campos et al., 2015; A. Chu, Lin, & Chiueh, 2017; Hemmati et al., 2021; Manocha & Babovic, 2017; Parandvash & Chang, 2016; Sampson, Quay, & White, 2016; Urich & Rauch, 2014; Xu et al., 2021). Scenario outputs from modeling-based approaches are mostly quantitative or spatial (Abadie, 2018; Apreda et al., 2019; Banu et al., 2014; Borris et al., 2016; Casal-Campos et al., 2015; K. Chen et al., 2017; X. Chen et al., 2021; A. Chu et al., 2017; Dubey et al., 2021; El-Fadel & Ghanimeh, 2013; Hemmati et al., 2021; Krummenauer et al., 2021; Manocha & Babovic, 2017; Parandvash & Chang, 2016; Park et al., 2021; Parkinson et al., 2016; Rohat, Flacke, et al., 2019; Sampson et al., 2016; Terama et al., 2019; Urich & Rauch, 2014; Wolff et al., 2020; Xu et al., 2021; Yan, Li, Wang, Ge, & Zhang, 2016; Zhu et al., 2020), although some studies combine quantified or spatialized projections with qualitative narratives of potential futures (Borris et al., 2016; Manocha & Babovic, 2017).

4.3. *Use of socio-economic projections throughout the adaptation planning process*

The results of this review suggest that the application of socio-economic projections has so far limited to three key stages of the urban adaptation planning process: assessing climate change risks and vulnerabilities, identifying adaptation options, and assessing and selecting adaptation options (see Table 4).

Evidence suggests that socio-economic projections are primarily used at the climate change risk and vulnerability assessment stage. At this planning stage, socio-economic scenarios can facilitate identification of local risks and assessment of future vulnerability at an urban scale (Birkmann et al., 2020, 2021; A. Chu et al., 2017; Meyer et al., 2019; Yan et al., 2016). Socio-economic projections can enhance a multifaceted understanding of risk and vulnerability in urban contexts

Table 4
Use of Socio-Economic Projections throughout the Urban Adaptation Planning Process. Note: some literature uses socio-economic projections at multiple stages of the planning process and is therefore categorized more than once. See SM2 for full categorization of literature.

Planning Stage	Sources (#)
Preparing the ground for adaptation	(0)
Assessing climate change risks and vulnerabilities	(32)
Identifying adaptation options	(7)
Assessing and selecting adaptation options	(10)
Implementing adaptation	(0)
Adaptation monitoring, evaluation and learning	(0)

by enabling dynamic analysis of human, economic, social, cultural and ecological systems across temporal and spatial scales (Ronco et al., 2014). A coupled approach to modeling future socio-economic and climate scenarios enables constant monitoring of risk and vulnerability in response to a wide range of potential changes (Apreda et al., 2019; Reimann, Vollstedt, et al., 2021). Socio-economic projections can also be used to visualize desirable futures and can act as a decision-support tool to guide strategic planning and policy making on adaptation. Participatory scenario-building approaches can help stakeholders visualize both desirable and undesirable futures which can be useful in identifying adaptation objectives and can serve as a starting point for backcasting possible pathways towards desired future visions (Birkmann et al., 2021; Ciumasu, 2013; Huang et al., 2011; Reimann, Vollstedt, et al., 2021).

When identifying and selecting adaptation options, socio-economic projections can be used to develop robust, flexible, and low-regret adaptation strategies that perform well under multiple futures (Jurgilevich et al., 2021; Manocha & Babovic, 2017; Rohat et al., 2021; Rohat, Wilhelmi, et al., 2019; Urich & Rauch, 2014). Scenario-based modeling approaches can help to identify priority areas for adaptation interventions (Birkmann et al., 2021; K. Chen et al., 2017; Dubey et al., 2021; Manocha & Babovic, 2017; Peng & Li, 2021; Wolff et al., 2020). Scenario approaches also enable performance assessment of climate adaptive design solutions under multiple future development and climate conditions (Apreda et al., 2019; Egger & Maurer, 2015; Hemmati et al., 2021; Jurgilevich et al., 2021; Manocha & Babovic, 2017; Sampson et al., 2016). Such performance assessment can provide a straightforward method for selecting adaptation options based on ranking of solutions according to their ability to reduce future risk and vulnerability under a wider range of potential development and climate pathways (Manocha & Babovic, 2017; Wan et al., 2020). This can contribute to an understanding of the costs and benefits of different adaptation solutions and can help to examine tradeoffs and prevent maladaptation (Hemmati et al., 2021; Jurgilevich et al., 2021).

4.4. Challenges and limitations of using socio-economic projections in urban adaptation planning

A number of challenges exist when utilizing socio-economic projections in urban adaptation planning. First, socio-economic projections are inherently uncertain (Ciumasu, 2013; Jurgilevich et al., 2021; Park et al., 2021; Rohat, Flacke, et al., 2019; Urich & Rauch, 2014) and the quality of scenario-based approaches depends closely on the assumptions used which often turn out to be unrealistic (Ciumasu, 2013; Urich & Rauch, 2014). In an urban context, the inherent uncertainty of projections is exacerbated due to the complex nature of urban systems (A. Chu et al., 2017).

Second, some existing socio-economic projections such as the SSPs are not useable at an urban scale. The SSPs were conceptualized at a global scale and therefore lack the specificity necessary to understand spatial patterns of local socio-economic development (Birkmann et al., 2021; Meyer et al., 2019; Reimann, Vollstedt, et al., 2021; Rohat, Wilhelmi, et al., 2019; Xu et al., 2021). This makes downscaling SSPs to an urban scale challenging and means that there is a lack of urban scale projections consistent with global SSPs (Rohat, Wilhelmi, et al., 2019).

Third, quantitative socio-economic projections are difficult to apply in data poor environments (Rohat, Flacke, et al., 2019). Local quantitative socio-economic data is often scarce in many contexts which means that scenarios are therefore highly simplified depictions of future socio-economic development and vulnerability (Birkmann et al., 2020, 2021; Rohat, Flacke, et al., 2019; Wolff et al., 2020). There is also often a temporal mismatch in socio-economic and climate data, with local socio-economic data often only available on timescales inconsistent with global climate scenarios (Birkmann et al., 2020; Wolff et al., 2020).

Finally, while using multiple knowledges and participatory techniques is recommended, bottom-up and participatory scenario development approaches can be time consuming and resource intensive. Likewise, the lack of a common methodology for bottom-up scenario development limits comparison across studies (Reimann, Vollstedt, et al., 2021). This challenge can be partially overcome by using global SSPs as boundary conditions for local scenario production. However, this may also be detrimental as it can limit creativity and result in scenarios that too closely mirror global projections (Reimann, Vollstedt, et al., 2021).

4.5. Recommendations for future use of socio-economic projections in urban adaptation planning

First, scenario approaches should more closely reflect locally specific trends. Further research should focus on developing modeling approaches and methodologies that are appropriate at an urban scale and consider the local spatial variability of development trends (Birkmann et al., 2020, 2021; Reimann, Vollstedt, et al., 2021; Rohat, Flacke, et al., 2019; Zhu et al., 2020). It is not sufficient to simply downscale socio-economic data from a national or global scale (Birkmann et al., 2021; Egger & Maurer, 2015). There is a need to develop case-specific scenarios in every urban context to effectively capture locally-specific development trends and needs.

Second, future research should work towards including more detailed socio-economic data in scenario development approaches. Including a wide range of demographic indicators such as age, sex, poverty, income, race, and education alongside data on health, land use, and biodiversity can enhance the ability of scenario assessments to assess future vulnerability and adaptive capacity in complex urban systems (A. Chu et al., 2017; Peng & Li, 2021; Reimann, Jones, et al., 2021; Rohat, Wilhelmi, et al., 2019; Terama et al., 2019).

Third, despite the necessity of developing locally-specific scenarios using urban scale data, it is still beneficial to maintain the consistency of local projections with global SSPs. Utilizing the SSPs as boundary conditions or 'mega trends' for urban scenario development enables comparison between multiple urban scenario applications and facilitates an understanding of the interlinkages between local and global socio-economic development patterns (Park et al., 2021; Reimann, Vollstedt, et al., 2021; Rohat, Wilhelmi, et al., 2019). While the literature reviewed argues that ensuring local-global consistency is key, it may be necessary to develop a wider range of potential development pathways than those currently captured by the SSPs. This would enable visualization of multiple potential avenues to sustainability beyond the globalized and growth-centered scenarios put forth by the five existing SSP narratives (Kamei et al., 2021).

Fourth, to ensure the relevance of socio-economic projections for context-based adaptation planning, future urban scenario applications should take a participatory approach by including stakeholders in the entire process. Local stakeholder input during scenario development is critical to ensure the relevance and credibility of scenarios and promote local ownership (Li et al., 2017; Meyer et al., 2019; Reimann, Vollstedt, et al., 2021; Rohat et al., 2021; Rohat, Wilhelmi, et al., 2019). However, it is important to note that participatory scenario development approaches can be challenging. It is therefore key to utilize carefully designed methodologies that ensure stakeholders have sufficient time to familiarize themselves with scenario development, establish clear roles for stakeholders in the scenario creation process, and promote good communication between stakeholders and researchers (Li et al., 2017; Reimann, Vollstedt, et al., 2021).

Finally, future research should more explicitly explore how to best utilize socio-economic scenario information in urban adaptation planning and governance (Jurgilevich et al., 2021). Urban socio-economic projections could be used to further explore vulnerability dynamics, assess the costs and benefits of different adaptation options, identify tradeoffs between adaptation and mitigation, and investigate maladaptation in urban adaptation planning and policy making (Jurgilevich et al., 2021; Rohat et al., 2021; Rohat, Flacke, et al., 2019).

4.6. Recommendations for future use of socio-economic projections to support urban climate justice

While the connection is unequivocal, none of the literature reviewed on socio-economic projections and urban CCA planning explicitly mentions equity or justice in relation to socio-economic projections or scenarios. However, some studies do refer to socio-economic projections as a tool to enhance understanding of future vulnerability and adaptive capacity (Birkmann et al., 2020, 2021; A. Chu et al., 2017; Ciumasu, 2013; Jurgilevich et al., 2021; Meyer et al., 2019; Peng & Li, 2021; Sampson et al., 2016), concepts that are arguably closely tied to justice.

5. Discussion

5.1. The limited application of socio-economic projections in urban adaptation planning

Despite the importance of considering future socio-economic development in adaptation decision-making, specific literature on socio-economic projections in urban CCA has only emerged recently and remains relatively undeveloped. In our study, only 41 articles on urban adaptation are found to consider socio-economic projections and no studies actively connect socio-economic projections to urban climate justice. When urban adaptation research does consider socio-economic scenarios, projections are developed either through participatory approaches that engage stakeholders in workshops, consultation, or participatory mapping or through modeling-based approaches that utilize downscaling or predictive and statistical modeling to generate future scenarios. The higher adoption of modeling-based approaches could be linked to the rise of neoliberal forms of climate urbanism wherein urban climate action primarily favors technocratic expertise and quantitative data (Robin & Castán Broto, 2021).

Our results point out that socio-economic projections are often only used at one stage of the planning process, with risk and vulnerability assessment being the most common phase during which to apply future socio-economic information. In general, this review indicates that urban adaptation research does not pay sufficient attention to socio-economic projections as a tool to prepare the ground for adaptation, implement adaptation, or monitor and evaluate adaptation interventions. This could be a missed opportunity, especially in relation to monitoring and evaluation processes (Ford & Berrang-Ford, 2016; Olazabal et al., 2019; Otto, Göpfert, & Thieken, 2021) that need to track how socio-economic development trends constantly shift alongside local adaptation needs (Westman et al., 2022). Integrated tracking of the environmental, social, and economic consequences of adaptation is one example of the forms of interdisciplinary urban governance that will be critical to enable effective responses to the 'compound urban crises' that our cities will face as urban climates and socio-economic development pathways shift into the future (Westman et al., 2022). Likewise, integrating socio-economic projections in the monitoring and evaluation of adaptation might be a very helpful tool to identify potential maladaptations (Eriksen et al., 2021).

The limited discussion on the use and applicability of socio-economic projections in urban adaptation literature to date could be due to the challenges with developing and applying projections in cities due to the unsuitability of global socio-economic projections for use at an urban scale. Due to the local specificity of development trends, approaches that attempt to downscale the SSPs to a local scale risk overlooking local conditions that can impact the severity of risk and the potential for adaptation (Frame, Lawrence, Ausseil, Reisinger, & Daigneault, 2018). Limited application of socio-economic projections in urban adaptation research could also stem from a lack of local data, a lack of know-how to collect appropriate data, difficulty in measuring certain indicators of socio-economic development, and the challenges of producing local bottom-up scenarios.

Whatever the reason for the somewhat limited application of socio-economic projections to date, the literature (Birkmann et al., 2020; Ciumasu, 2013; Huang et al., 2011; Reimann, Vollstedt, et al., 2021; Rohat et al., 2021; Rohat, Flacke, et al., 2019; Terama et al., 2019) clearly points to the urgent need to better incorporate future socio-economic data into urban adaptation research due to the deep uncertainty of future climate and development trajectories and, perhaps more notably, due to the potential tendency for socio-economic changes to have a greater influence on future urban risk and vulnerability than climatic changes.

5.2. The potential for socio-economic projections to promote urban climate justice

Despite the current lack of specific attention to the connection between socio-economic projections and urban climate justice, the thematic analysis of the literature illustrates that utilizing socio-economic scenarios in urban adaptation planning could have the potential to promote urban climate justice in several ways. Although the literature does not explicitly connect the concepts of justice and socio-economic projections, the ways in which socio-economic projections are applied in adaptation literature often align closely with principles for supporting urban climate justice. Through an interpretation of the findings of our review, we summarize this in Fig. 3.

First, socio-economic projections could be used as a tool to ensure distributive justice in cities if socio-economic scenario analysis is used to select adaptation options that provide equitable access to urban space and services for all across multiple potential futures. Socio-economic projections offer a new form of data that can help decision-makers analyze distributive justice outcomes and make choices that maximize justice both today and in future development scenarios. Approaches that aim to develop adaptation pathways or select robust, no-regret, and flexible solutions could be especially beneficial in promoting justice as these strategies could be regularly adjusted to improve justice outcomes in the future. Flexible, no-regret solutions lie in contrast to the protective solutions that we often see implemented today. A shift towards implementing flexible adaptation could help secure justice outcomes as these solutions allow potential for change as both climate future and socio-economic development pathways unfold.

Second, participatory scenario development approaches could have the potential to strengthen procedural justice. Participatory approaches that embed stakeholder participation in the entire process of scenario design could be pursued to ensure that participation is present at every stage of the planning and decision-making process. Participatory socio-economic scenario analysis may be well suited to promoting procedural justice because it embeds participation of stakeholders and citizens not only in the selection of desirable adaptation solutions but in a much more fundamental process of defining which potential futures to plan for. This type of integrated stakeholder participation is rarely seen in adaptation planning processes today, where the norm is shallow and tokenistic participation that does not extend to the entire planning process. Furthermore, scenario development approaches that strive to ensure broad participation beyond traditional 'expert' stakeholder participation strategies could have the potential to elevate voices that are often not heard in the context of decision making on adaptation. This could expand the current context of stakeholder participation which often only suceeeds in including stakeholders that already have power and voice in decision making processes, despite attempts at broad and diverse inclusion. Participatory scenario development approaches are especially critical to ensure just and effective adpatation in local contexts where socio-economic development trajectories are guided by informal processes such as the expansion of informal settlements that may not be well understood by 'expert' stakeholders (Pandey, Yangchen, Thiyaharajan, & Kishwan, 2023).

Third, recognition and restorative justice could be promoted through the use of socio-economic projections to aid in the selection of adaptation options that explicitly prioritize vulnerable groups. Socio-economic

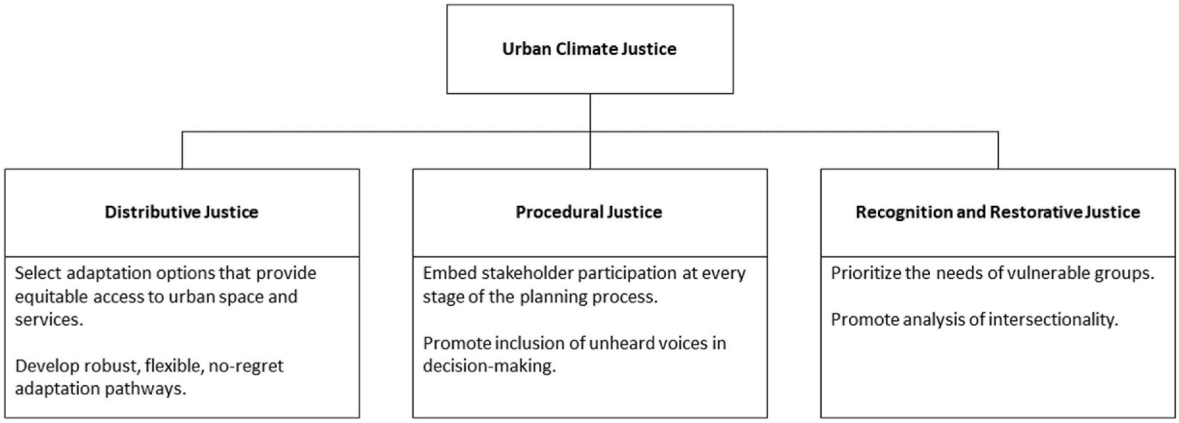

Fig. 3. Potential for socio-economic projections to promote urban climate justice.

scenario analysis could also potentially help to better assess the intersectionality of urban climate justice with other urban justice issues. Coupled socio-economic and climate projections integrate a wide range of indicators and can thus enablea comprehensive analysis of future vulnerability. Therefore, socio-economic projections could help to facilitate the identification of drivers of injustice across spatial and temporal scales and between possible future scenarios. Socio-economic projections can thus be seen as a tool to explicitly analyze and address root causes of vulnerability and injustice.

While socio-economic projections show great potential for promoting all pillars of urban climate justice, not all scenario development and application approaches are equally useful for ensuring just adaptation across all stages of planning. To avoid maladaptation and promote just urban transitions, socio-economic projection applications should explicitly strive to ensure distributive, procedural, recognition and restorative justice. Justice should be a key consideration when applying socio-economic projections at each stage of the urban adaptation planning process. Table 5 provides a framework for using socio-economic projections in urban adaptation to promote justice, specifically outlining actions that decision makers can take at each stage of the planning process to ensure the just application of socio-economic projections.

When preparing the ground for adaptation, procedural justice can be supported by conducting a broad and inclusive stakeholder analysis and identifying key sources of local knowledge. A participatory socio-economic scenario process supports consideration of procedural justice early in the planning process. When assessing climate change risks and vulnerabilities, an approach grounded in socio-economic scenario analysis has the capacity to support procedural justice outcomes by closely engaging stakeholders in defining future scenarios and identifying future needs and priorities. A collaborative process of future vulnerability analysis can also support distributive justice by making patterns of vulnerability and risk spatially explicit in both current and future scenarios. When identifying adaptation options and assessing and selecting adaptation options, decision makers will be able to integrate findings from the participatory scenario development process in relation to local needs, desired futures, and patterns of historical injustice. The close consideration of local perspectives when selecting adaptation options can, for example, avoid increased vulnerability as a result of climate gentrification that is so often associated with implementation of green infrastructure and nature based solutions (Rice, Cohen, Long, & Jurjevich, 2020; Shokry, Connolly, & Anguelovski, 2020). Finally, when implementing adaptation and carrying out monitoring and evaluation processes, socio-economic scenario data can provide a means to regularly re-evaluate the socio-economic efficacy of solutions. This can make adaptation decision making more dynamic across both hazard and vulnerability dimensions, thus supporting proactive consideration of distributive and procedural justice.

It is important to note that this framework aims to inspire scientists and practitioners and does not intend to act as a one-size-fits-all guide for applying socio-economic projections in support of urban climate justice. Each local context is unique, and actions need to be contextualized to best respond to local needs or cope with context-specific financial, policy and planning constraints that are diverse and vary across cities. Combining the framework with other concepts such as Climate Resilient Development Pathways (CRDP) (Roy et al., 2018) could prove useful, and may address one or more of the knowledge gaps that exist in relation to climate resilient development (CRD). According to Schipper et al. (2022, p. 2732) these include (but are not limited to) "how different CRD pathways can be designed such that they illustrate opportunities for the practical pursuit of CRD in a manner consistent with principles of inclusion, equity and justice", and "best practices for avoiding maladaptation and ensuring that adaptation interventions are designed so they do not exacerbate vulnerability to climate change to support CRD". They further conclude that distributive and procedural justice are key criteria for evaluating climate action generally and CRD specifically, and that failure to do so may hinder rather than accelerate climate resilient development. It is also important to note that future oriented planning approaches that strive to combine climate and socio-economic scenarios in pursuit of justice should not underestimate the role of colonial pasts in shaping adaptive capacity. Careful attention must be paid to how socio-economic pasts shape socio-economic futures (Robinson, Douma, Poore, & Singh, 2023).

6. Conclusions

We here present an initial exploration on how existing urban adaptation literature discusses use of socio-economic projections in urban adaptation planning and policy and their capacity to ensure climate justice. Six key themes emerge from the literature: (1) justifications for using socio-economic projections in urban climate change adaptation, (2) types of socio-economic projections and methods of scenario development, (3) their use throughout the adaptation planning process, (4) challenges and limitations, (5) recommendations for further research on projections in urban adaptation planning, and (6) socio-economic projections as a tool to promote urban climate justice. While the potential of socio-economic projections as a tool to enable more justice-centered urban adaptation planning is significant, none of the literature reviewed specifically discussed this. Our analysis, however, offers a foundation to depict a preliminary framework on how this can be done in urban adaptation planning practice by identifying specific activities where socio-economic projections have an important role and connected justice elements.

To continue exploring pathways to a more inclusive data-driven urban adaptation planning, we recommend further research in four areas: (1) local data availability and diversity to reflect justice complexity, (2) local-global consistency of socio-economic scenario data

Table 5
Framework for justice-centered application of socio-economic projections in urban climate change adaptation planning.

Planning stage	Action	Main justice element
Preparing the ground for adaptation	Conduct broad and inclusive stakeholder identification process	Procedural
	Identify relevant sources of local knowledge	Procedural
Assessing climate change risks and vulnerabilities	Consult stakeholders to identify future socio-economic development challenges and future needs	Procedural
	Develop scenario narratives of multiple potential desirable and undesirable socio-economic futures with stakeholders	Procedural
	Quantify and spatialize future scenarios with the help of local experts and embed scenarios within SSP narratives to enable spatial assessment of future risk and vulnerability at a neighborhood scale	Distributive Procedural
Identifying adaptation options	Consider stakeholder suggestions gained during participatory scenario development when identifying adaptation options	Procedural
	Identify potential solutions that provide benefits for all and explicitly prioritize the needs of vulnerable groups	Distributive Recognition and Restorative
Assessing and selecting adaptation options	Select flexible adaptation solutions that can perform well under multiple socio-economic futures	Distributive
	Select adaptation solutions that explicitly prioritize the needs of vulnerable and marginalized groups	Recognition and restorative
	Promote intersectionality by selecting multifunctional adaptation options that respond to climate justice challenges while also addressing other local drivers of injustice	Recognition and Restorative
Implementing adaptation	Embed socio-economic scenario data into all strategic planning and policy-making efforts	Distributive Procedural Recognition and restorative
Adaptation monitoring, evaluation, and learning	Regularly update socio-economic scenarios based on new information and consult with stakeholders often to understand changing needs and assess the effectiveness of adaptation solutions	Distributive Procedural

to contextualise local dynamics within worldwide processes, (3) empirical research approaches beyond these theoretical insights to better understand how applications of socio-economic projections influence justice outcomes on the ground and (4) application of socio-economic projections when identifying adaptation options, assessing and selection adaptation options, and implementing adaptation to not only improve justice outcomes but also potentially support the adoption of more innovative urban adaptation. Overall and based on the findings of this explorative study, we argue that socio-economic projections show remarkable potential to promote new definitions of inclusive, justice-centered data-driven governance in cities, that are, ideally, context-specific. Neither science nor policy practice (Olazabal et al. 2019, 2021) seem to take the baton on this avenue. We here make a call for further research in this arena to pave the way for more transformative and just urban adaptation practices on the ground.

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Author contributions

MO and MP participated in the conception and design of the research. MP performed the analysis and drafted the article text. MO and ML contributed significantly to the revision of the text and refinement of the research design, as well as to the discussion and conclusions.

Data availability

All data generated and analyzed in the research is available in the supplementary material file provided.

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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.habitatint.2023.102946.

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