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The Role of Non-Climate Data in Equitable Climate Adaptation Planning: Lessons from Small French and American Cities

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Abstract: There is a growing consensus that to effectively adapt to climate change, cities need user-friendly tools and reliable high-resolution biophysical and socio-economic data for analysis, mapping, modeling, and visualization. This study examines the availability of various types of information used in climate adaptation plans of 40 municipalities with a population of less than 300,000 people in the United States and France, probing into the choice and usage of relevant information by small municipalities. We argue that non-climatic spatial data, such as population demographic and socio-economic patterns, urban infrastructure, and environmental data must be integrated with climate tools and datasets to inform effective vulnerability assessment and equitable adaptation planning goals. Most climate adaptation plans examined in this study fail to address the existing structural inequalities and environmental injustices in urban infrastructure and land use. Their challenges include methodological and ideological barriers, data quality issues, and a lack of meaningful community connections. Adaptation methodological approaches should be reassessed in the context of much-needed societal transformation. Lessons learned from our studies offer valuable insights for the potential development of national and state-level climate adaptation information services for cities.

Keywords: climate change adaptation; adaptation plan; small municipality; France; United States; climate services; information

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1. Introduction and Background

This study contributes to the growing international body of knowledge on climate services and data intended for climate change adaptation planning at a local scale. Climate services for adaptation have been defined as all public and private sector services supporting adaptation to climate change [1,2]. Based on [3] "the aim of climate services is to provide people and organizations with timely, tailored climate-related knowledge and information that they can use to reduce climate-related losses and enhance benefits, including the protection of lives, livelihoods, and property" (p. 588). The European Union further defines climate services as a process of "transforming climate-related data and other information into customized products such as projections, trends, economic analyses, advice on best practices, the development and evaluation of solutions, and any other climate-related services that may be of use for society" [4]. There has been significant progress toward improved climate change scenarios, downscaling, theoretical and methodological development, and production of applied tool-kits, and online clearinghouses intended to support climate adaptation planning at a city scale, produced collaboratively by national and international governmental entities and research institutions [5–8]. There is also a growing recognition that effective climate adaptation planning requires the analysis of multidisciplinary data, which is not limited to climate change trends and scenarios alone. The integration of climate and weather data with social, economic, cultural, and environmental data is paramount to evaluate the present and future human vulnerability to climate change, addressing disproportionate socioeconomic risk to climate impacts and engaging overburdened communities in the planning process [9–11]. A growing number of organizations have developed various services to assist local governments and communities with climate adaptation planning. Examples of international platforms include the Global Framework for Climate Services (GFCS) of the World Meteorological Organization [12], Copernicus Climate Change Service (C3), the EUMETSAT (European Organization for the Exploitation of Meteorological Satellites), and Climate-ADAPT [6] of the European Union [13]. National and regional instruments, such as the U.S. Climate Resilience Toolkit [14], Climate Adaptation Knowledge Exchange (CAKEX) by Eco-Adapt [15], Adapt West [16], the Great Lakes Integrated Science and Assessment (GLISA) [17], the French National Observatory on the Effects of Global Warming (ONERC), the National Ecological Transition Agency (ADEME), and the platform ClimatHD by Meteo France offer more specific country-wide or region-wide data coverage. Some U.S. states, such as California, provide state-level open access peer-reviewed cross-disciplinary data and collaboration opportunities to stakeholders, including infrastructure managers, municipal planners, community-based organizations, state agencies, scientists and climate experts, educators, and the public via Cal Adapt [7]. These databases provide state-wide data on temperature, rainfall, wind, soil moisture, and ocean conditions, as well as maps, risk and vulnerability analyses, assessments, and long-term projections and scenarios. They can be combined with socio-economic variables and non-meteorological data such as agricultural production, health trends, human settlement in high-risk areas, and road and infrastructure maps for the delivery of goods, depending on user needs and other relevant information.

In France, since 2011, ten regional working groups of independent experts have been created to support regional climate change monitoring efforts. These include five existing groups—AcclimaTerra in Nouvelle-Aquitaine, GREC-SUD in Provence-Alpes-Côte d'Azur, Ouranos-AuRA in Auvergne-Rhône-Alpes, RECO in Occitanie, GREC Guadeloupe and five more groups still being formed in Brittany, Normandy, Pays de La Loire, Ile-de-France, and Hauts-de-France. These multidisciplinary committees are modeled after IPCC Working Groups and are positioned at the interface of academic and non-academic spheres, constituting a catalyst for action in response to the impacts of climate change. The Nouvelle-Aquitaine region, which currently holds the most climate adaptation plans in the country, is home to AcclimaTerra [18], the precursor group that pioneered this initiative in 2018 [19]. Similar regionalization of metropolitan climate adaptation planning has been observed in the United States for many years with Regional Adaptation Planning (RAP) initiatives evolving around major cities and involving municipalities of various sizes. Metropolitan RAPs assume diverse organizational arrangements and operate in a variety of political and geographical contexts, including the development of their own climate services. Their spatial scale varies from parts of urban agglomerations to bioregional watersheds, but in the United States they most commonly reflect the boundaries of existing "metropolitan regional" entities, such as counties and regional planning organizations [20].

Since the purpose of climate adaptation is the reduction in vulnerability to adverse climate impacts, any climate adaptation plan should be based on a thorough assessment of human vulnerability and principles of climate justice. Therefore, climate services for climate adaptation planning are inherently multidisciplinary and must include demographic, social, economic, and environmental justice data and tools as well. Justice is a legal term closely related to the social concept of equity, offering a human rights perspective on the climate crisis, acknowledging that climate change has differing social, economic, public health, and other adverse impacts on underprivileged populations [21]. Developing transparent planning strategies that eliminate disparities would be impossible without reliable social and economic data about race, class, gender, and other dimensions of diversity. To address this need, several U.S. states, e.g., Michigan [22], are currently developing Environmental Justice Screens—online platforms providing environmental justice spatial data at a much higher resolution than the already existing U.S. EPA EJ Screen [23]. In France, the discourse on environmental justice remains mostly confined to academia. While a focus on racial discrimination has been at the heart of the U.S. environmental justice movement [24,25], the concept of "race" as a major factor of environmental injustice is still barely acknowledged in France, mostly due to the effort of its republican ideology to erase any recognition of racial inequalities [26].

Despite progress in the development of climate services for adaptation planning, including some non-climatologic data, there is still a significant gap between the actual data needs and existing products and services offered by various organizations. This gap is particularly problematic for small municipalities, which have limited capacity to locate, access, and interpret adequate information, compared to large high-capacity cities. Cross-national peer-learning experience is rarely available to smaller communities [27] and very few scholarly studies have compared the provision of climate services for local climate adaptation planning between different countries [28,29]. One significant challenge is that climate services largely develop through interaction between the scientific and non-scientific communities, whereas scientific literature is built mostly through exchange within the academic sphere. As Vaughan et al. point out "While several outlets allow members of specific research communities to communicate with each other, there are far fewer mechanisms that allow operational climate service providers and consumers to engage in two-way dialog on the questions they would like addressed by the research community. This two-way communication is essential given the overwhelming evidence that climate services are most useful when they are developed as part of an iterative process of "co-discovery", "co-development," and "co-evaluation" involving the producers and users of climate information" [30]. Thus, an analysis driven by the users' perspective is necessary to go beyond the academic discussions and incorporate knowledge and data generated by communities themselves.

The primary objective of our study is to examine climate adaptation data needs from the perspective of small municipalities (defined here as urban areas with populations less than 300,000). The U.S. and France provide an especially interesting case due to fundamental differences in their approaches to local climate adaptation planning and provision of climate services, with the French system being highly centralized and a variety of community-driven approaches across the United States. Our secondary objectives are to investigate what information, methods, and tools have been used in local vulnerability assessments and climate adaptation plans in both countries, to identify major gaps, and to synthesize insights from these two different national models of local climate adaptation planning. We do not aim here to compare different national approaches. Instead, our goal is to use this cross-national case study to provide some insights into common challenges faced by small municipalities and emerging solutions in both countries.

2. Methodology

2.1. Climate Adaptation Plans

This inquiry on the role of multidisciplinary data and tools available for municipal climate adaptation planning is informed by the analysis of climate adaptation plans and vulnerability assessment reports developed by urban and rural municipalities with populations less than 300,000 people in the U.S. and France. To investigate the content, sources, and scale of climatic and non-climatic tools, services, and data used by the local communities we examined 40 published climate adaptation plans (23 in the U.S. and 17 in France) of small cities, towns, and counties. The selection of planning documents for the U.S. part of the dataset is described in detail in [31], while the selection of both U.S. adaptation plans and French PCAETs (Plan Climat Air Energie Territorial) is the most recent update of our earlier dataset published in [27] and [32]. Climate adaptation planning in France has been fully integrated into local territorial climate-air-energy plans, which are now mandatory for all communities with more than 20,000 inhabitants [33]. On the contrary, climate adaptation efforts in the United States have been voluntary and mostly driven by state, local, and tribal initiatives [34]. The sample of municipalities is not meant to be exhaustive and aims to reflect the geographic diversity of both countries. These cities, towns, and counties are listed in Table 1, with a summary of climate change impacts addressed in their climate adaptation plans.

Table 1. U.S. and French climate adaptation plans.

Municipality	Source	Impacts of Climate Change Addressed							
		Coastal Changes	**Severe Storms**	**Extreme Heat**	**Extreme Cold**	**Flooding**	**Drought**	**Wildfires**	**Seasonal Shifts**
U.S. climate adaptation plans									
Albany, NY	[35]		X	X	X	X			X
Alger County, MI	[36]	X	X	X	X	X	X	X	X
Boulder County, CO	[37]			X	X	X	X	X	
Chula Vista, CA	[38]	X	X	X		X	X	X	
Corte Madera, CA	[39]	X	X	X		X	X	X	
Flagstaff, AZ	[40,41]		X	X		X	X	X	X
Georgetown, ME	[42]	X	X			X			
Groton, CT	[43]	X	X	X		X	X		X
Iowa City, IA	[44,45]		X	X		X	X		X
Keene, NH	[46,47]		X	X	X	X	X		X
Laguna Woods, CA	[48]		X	X		X	X	X	
Marquette, MI	[49]	X	X	X		X	X		X
Marquette County, MI	[50]	X	X	X	X	X	X	X	X
Marshfield, MA	[51]	X	X	X	X	X			X
North Kingston, RI	[52]	X	X	X	X	X			X
Punta Gorda, FL	[53,54]	X	X	X		X			
Salem, MA	[55]	X	X	X		X			
Santa Cruz, CA	[56,57]	X	X	X		X	X	X	
Sarasota, FL	[58,59]	X	X	X		X			
Taos County, NM	[60]		X	X		X	X	X	X
Tybee Island, GA	[61]	X	X			X			
Tompkins County, NY	[62]		X	X		X	X		
Watsonville, CA	[63]	X	X	X		X	X	X	
French climate adaptation plans									
Brest métropole, Bretagne	[64,65]	X	X	X		X	X		
Clermont Auvergne Métropole, Auvergne-Rhône-Alpes	[66–69]			X		X	X	X	
Cordais et Causse (4 C), Occitanie	[70–72]					X		X	
Golfe du Morbihan, Bretagne	[73]	X	X			X			
La ivière du Levant, Guadeloupe	[74]	X		X					X
Le Grand Chalon, Bourgogne-Franche-Comté	[75,76]			X		X			X
Niortais, Nouvelle-Aquitaine	[77,78]			X		X	X		
Pays de Barr, Grand Est	[79–81]			X		X	X		X

Table 1. *Cont.*

Municipality	Source	Impacts of Climate Change Addressed							
		Coastal Changes	Severe Storms	Extreme Heat	Extreme Cold	Flooding	Drought	Wildfires	Seasonal Shifts
Pays Dieppois—Terroir de Caux (PDTC), Normandie	[82–85]	X		X		X			
Pays Voironnais, Auvergne-Rhône-Alpes	[86]			X		X		X	X
Perpignan Méditerranée Métropole, Occitanie	[87]	X		X		X	X		
Saint Omer—CAPSO, Hauts-de-France	[88–90]			X		X	X		
St-Quentin-en-Yvelines—CASQY, Ile de France	[91,92]			X					
Sud-Estuaire, Pays de la Loire	[93–96]					X			
Sundgau, Grand Est	[97–99]					X	X		X
Vallée de Chamonix-Mont-Blanc, Auvergne-Rhône-Alpes	[100,101]								X
Var Esterel Méditerranée, Provence-Alpes-Côte d'Azur	[102,103]	X	X	X		X			

2.2. Conceptualization of Vulnerability

An adaptation plan is a road map to reducing human vulnerability to the current and future impacts of climate change. Adaptations seek to adjust human–environmental systems in response to actual or expected climatic stimuli to minimize their harm or exploit beneficial opportunities [104]. Therefore, adaptation planning always starts with an assessment of existing and projected vulnerabilities to climate impacts. The need to assess vulnerability to climate change is based on the acknowledgment that actual losses caused by hazard events such as storms, floods, or droughts are not solely a result of climate change but also determined by societal and economic preconditions that shape the way in which people are prepared for or respond to such events [105]. How vulnerability is defined and assessed largely shapes the agenda and priorities of adaptation planning and provides an essential baseline for measurable goals. It also determines the content of information and tools necessary to establish present and future climate adaptation goals. The discourse about vulnerability within climate change adaptation and climate risk scholarly literature encompasses various interpretations of the concept of vulnerability. Since the 2012 IPCC SREX report [106] and within the newer conceptualization of climate risks in the IPCC Assessment Reports Five [104] and Six [107], there is an emerging consensus that vulnerability is better framed as a starting point rather than an outcome. Approaches that conceptualize vulnerability as an outcome often include hazard information and therefore do not sufficiently differentiate between vulnerability and risk [105]. In the pre-SREX conceptual framework, vulnerability was considered as "a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" [108]; while under the newer framework, sensitivity and adaptive capacity are considered internal aspects of vulnerability, as opposed to exposure, conceptualized as an external factor [104,109]. This shift reflects the reconceptualization of vulnerability as a socioeconomic variable. In practice, both frameworks have been operationalized by scholars and agencies have continued to follow the IPCC AR4 definition of vulnerability [31,110]. In place-based community-scale assessments [111–113] vulnerability is most commonly conceptualized as a composite variable defined by both biophysical and socioeconomic factors of exposure, sensitivity, and adaptive capacity as a combination of geographical, demographic, and socioeconomic indicators [114].

In the absence of national or international climate adaptation and vulnerability assessment standards, it is inevitable for different municipalities to adopt diverse approaches to their vulnerability assessments. These different conceptual frameworks are summarized in Table 2. In theory, vulnerability assessment is meant to be objective to provide a reliable baseline for adaptation planning. In practice, however, vulnerability assessments are highly subjective because they depend on the philosophies and value orientations of organizations and stakeholders who conduct them [31]. Therefore, we use here the term "perceived vulnerability", commonly used in social and clinical psychology [115,116] as a measure of subjective perception of vulnerability by groups of the population. In health behavior theories, perceived vulnerability reflects a belief about the likelihood of a health threat's occurrence or the likelihood of developing a health problem or being exposed to infections or natural disasters [116,117]. We find this concept highly relevant for describing the collective beliefs of communities about the likelihood of being vulnerable to climate change.

Table 2. Information used in climate adaptation plans.

Area of Interest	Information Used in Climate Adaptation Plans
(a) **Conceptualization and assessment of vulnerability**	
As a synonym of exposure (omit sensitivity and adaptive capacity)	Climate change trends, climate change scenarios, risk analysis
As a combination of exposure, sensitivity, and adaptative capacity (pre-IPCC-SREX)	Climate change trends, climate change scenarios, risk analysis, demographic, health, and socio-economic data
As a combination of sensitivity and adaptive capacity to projected climate risks (post-IPCC-SREX)	Demographic, socio-economic, health statistics and risk analysis based on climate change trends and scenarios
As a combination of exposure and sensitivity (omit adaptive capacity)	Climate change trends, climate change scenarios, risk analysis, demographic data
As a combination of exposure and adaptive capacity (omit sensitivity)	Climate change trends, climate change scenarios, risk analysis, socio-economic data
(b) **Consideration of climate justice in adaptation goals related to:**	
Green and blue infrastructure	Climate, ecological and environmental data
Housing	Housing inventory and plans
Energy security	Energy access, cost, and future projections
Public transportation	Transportation networks and plans
Utilities	Utilities infrastructure and plans
Emergency services	Emergency infrastructure and plans
Food security	Food access, safety, and security data and projections
Water quality	Water quality data and scenarios
Air quality	Air quality data and scenarios
Community education	Information about education attainment and community education resources
Insurance	Insurance access data and scenarios
Community health	Health statistics trends, data about access to health care, and projections
(c) **Groups of stakeholders involved in data co-production and planning**	
Local citizens	Stories, survey, and focus group input, art, traditional knowledge, citizen science
Environmental and climate advocacy groups	Environmental and climate data, case studies, stories, non-scientific articles, blogs
Social justice advocacy groups	Environmental and climate data, case studies, stories, non-scientific articles, blogs
Local government officials	Policy connection, litigation, public mobilization, public funding
City planners	Urban, land-use, environmental spatial data, case studies, ordinances, litigation
Members of state or federal/national agencies	Guidelines, toolkits, case studies, science/policy connection, public funding, training materials
Academic institutions	Guidelines, toolkits, scholarly literature, spatial data, scenarios, public lectures
Local businesses	Surveys and focus group input, private funding
External consulting firms	Climate, geoscience, and environmental data, risk analysis, impact scenarios

2.3. Conceptualization of Equity and Inclusion

Consideration of climate justice is fundamental to reducing human vulnerability and providing adaptation benefits for all residents and neighborhoods. Climate justice can have distributive and procedural forms [118], where the former relates to the distribution of adverse impacts of climate change and the latter to how and by whom adaptation planning decisions should be made [21]. In climate adaptation planning, equity and justice imply planning strategies to eliminate disparities and create physical and social environments that aim to ensure a fairer distribution of community resources along race, class, gender, and other dimensions of diversity [119]. Municipalities that examine their vulnerability beyond biophysical climate impacts and consider the demographic, social, and economic characteristics of their populations appear to be more likely to develop specific measures focusing on vulnerable groups [31,120]. To identify cities' information needs for equitable planning, we consider twelve (12) climate adaptation domains frequently addressed in climate adaptation plans: *green and blue infrastructure, housing, energy security, public transportation, utilities, emergency services, food security, water quality, air quality, community education, insurance,* and *community health* (Table 2).

There is also growing consensus that transparent, actionable, and equitable adaptation planning requires inclusivity [121], engagement of diverse stakeholders, especially vulnerable groups, and integration of scientific and community knowledge [122], including traditional and indigenous knowledge in the process of climate service co-production [123,124]. In this study, we examine the participation of nine (9) types of stakeholders, directly and indirectly, in the co-production of information used in vulnerability assessment and the co-development of local climate adaptation plans. These are *local citizens, environmental and climate advocacy groups, social justice advocacy groups, elected officials, planners, members of state, federal/national agencies, academic institutions, local businesses,* and *external consulting firms* (Table 2).

2.4. Data Analysis

Each climate adaptation plan, including its bibliographic sources and metadata, was screened for information about the content and sources of methodologies and data used in vulnerability assessment and formulation of adaptation goals. The qualitative assessment includes three components driven by the following questions:

- How is the concept of human vulnerability defined and what information is used to assess it?
- How climate justice is addressed in climate adaptation goals across various sectors, and what information is used to formulate the goals?
- What groups of stakeholders are involved in the co-production of information used in vulnerability assessment and the co-development of local climate adaptation plans?

3. Results and Discussion

Table 3 provides a summary of our findings about vulnerability assessment, used as a basis for adaptation planning, consideration of justice, and the participation of stakeholders and co-production of information and climate adaptation plans.

Table 3. Areas of interest and information addressed in climate adaptation plans.

Area of Interest	U.S. Plans	French Plans
1. **Conceptualization and assessment of vulnerability**		
As a synonym of exposure (omit sensitivity and adaptive capacity)	5 (22%)	6 (35%)
As a combination of exposure, sensitivity, and adaptive capacity(pre-IPCC-SREX)	9 (38%)	3 (18%)
As a combination of sensitivity and adaptive capacity to projected climate risks (post-IPCC-SREX)	2 (9%)	0 (0%)
As a combination of exposure and sensitivity (omit adaptive capacity)	2 (9%)	0 (0%)
As a combination of exposure and adaptive capacity (omit sensitivity)	5 (22%)	8 (47%)
2. **Consideration of justice in climate adaptation goals related to:**		
Green and blue infrastructure	11 (48%)	4 (24%)
Housing	8 (35%)	14 (82%)
Energy security	6 (20%)	10 (59%)
Public transportation	8 (35%)	6 (35%)
Utilities	5 (22%)	2 (12%)
Emergency services	12 (52%)	7 (41%)
Food security	4 (17%)	13 (76%)

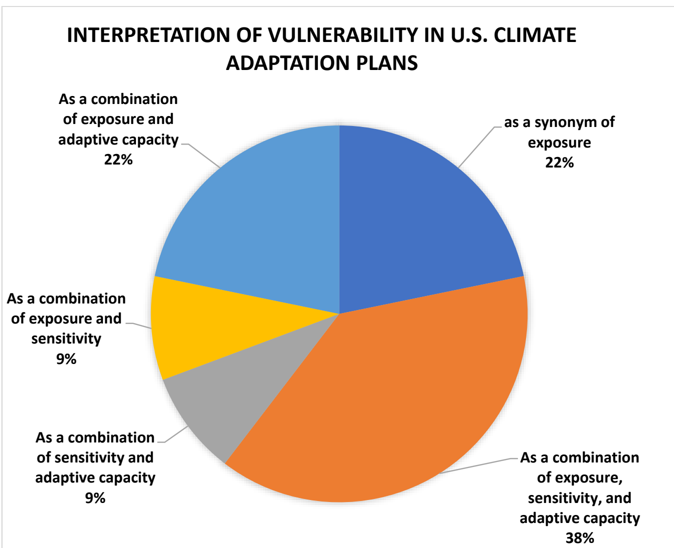
Table 3. *Cont.*

Area of Interest	U.S. Plans	French Plans
Water quality	4 (17%)	5 (29%)
Air quality	3 (13%)	1 (6%)
Community education	11 (48%)	9 (53%)
Insurance	2 (9%)	0 (0%)
Community health	7 (30%)	7 (41%)
3. **Groups of stakeholders involved in data co-production and planning**		
Local citizens	18 (78%)	9 (53%)
Environmental and climate advocacy groups	16 (70%)	8 (47%)
Social justice advocacy groups	6 (26%)	2 (12%)
Local government officials	22 (96%)	16 (94%)
City planners	21 (91%)	17(100%)
Members of state or federal/national agencies	12 (52%)	8 (47%)
Academic institutions	15 (65%)	3 (18%)
Local businesses	14 (61%)	13 (76%)
External consulting firms	13 (57%)	5 (29%)

3.1. Assessment of Human Vulnerability

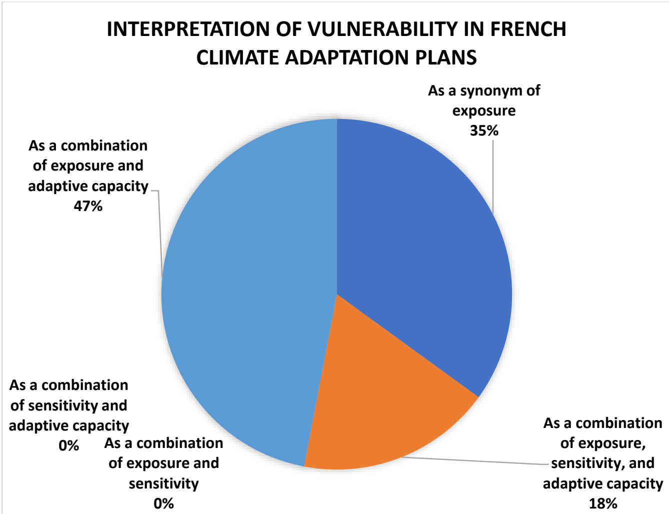
All municipalities examined in this study conducted their vulnerability assessments, either prior to or as a part of their climate adaptation process. However, using different guidelines from various sources based on different schools of thought, they define and interpret vulnerability in a variety of ways.

Figure 1a,b illustrate how the definition of vulnerability chosen by municipalities can pre-determine their focus on different dimensions of vulnerability and, consequently, different types of information used as a basis for their adaptation strategies. Out of 23 U.S. municipalities (Figure 1a), only two recently revised plans (9% of the sample) followed the post-SREX IPCC framework differentiating between social vulnerability (sensitivity and adaptive capacity) and external hazard exposure. Nine plans (38%) adopted the pre-SREX IPCC definition combining metrics of exposure, sensitivity, and adaptive capacity. The older conceptual framework appears to be by far the most popular in climate adaptation guidelines and municipal plans. Likewise, in the scholarly literature on adaptation planning, the newer IPCC framework was not quite as well accepted, and a vast majority of research articles published after SREX and the IPCC Fifth Assessment Report adopted the earlier conceptualization [110,125].



(a)

Figure 1. *Cont.*



(**b**)

Figure 1. Interpretation of vulnerability in (**a**) U.S. climate adaptation plans, and (**b**) French climate adaptation plans.

Interestingly, five more U.S. plans (22%) refer to the older IPCC framework in their methodologies, but in practice, address only exposure and adaptive capacity metrics and entirely omit sensitivity variables (such as age, gender, race, disability status, and wellness). In addition, two U.S. plans (9%), which refer to the same definition, address only exposure and sensitivity metrics and omit adaptive capacity. Finally, five remaining U.S. plans (22%) omit social and economic factors altogether, assessing vulnerability as *exposure* to various biophysical climate-change-related hazards. Four of these five were among the very first climate adaptation plans in the country, developed in the 2000s, reflecting the interpretation of this concept in the scholarly literature prior to the Third Assessment Report of the IPCC [126], but one of these plans was published in 2017.

French climate adaptation plans follow more uniform national guidelines and adopt only three versions of vulnerability assessment frameworks (Figure 1b). Almost half of them (47%) interpret vulnerability as a combination of biophysical factors of exposure to climate impacts and economic factors of adaptive capacity. While IPCC reports are routinely cited in plans' introductions, none of them follow the post-SREX IPCC framework and only three French plans (18%) adopted the pre-SREX IPCC framework. Six French plans (37%) equate vulnerability with exposure. Although the term *sensibilité* is frequently used in all plans, which can be literally translated into English as *sensitivity*, it is understood and assessed solely as biophysical exposure. For example, the "sensitivity" of a city's population to flooding risk is discussed and assessed based on precipitation scenarios rather than a differentiated analysis of population demographics as might be expected in the English-language climate adaptation literature.

3.2. Consideration of Justice in Climate Adaptation Goals

Adaptation plans must be equitable and fairly protect all residents, especially the most vulnerable groups. However, it is apparent that many adaptation plans do not set justice-centered priorities (Figure 2). Equitable access to emergency services and community climate education come up as the top activities addressed in both countries, yet only about half of all plans set such goals. French plans are more frequently concerned with equity in housing (82%), food security (76%), and energy security (59%); whereas 48% of U.S. plans set objectives for more equitable access to green infrastructure and ecosystem services.

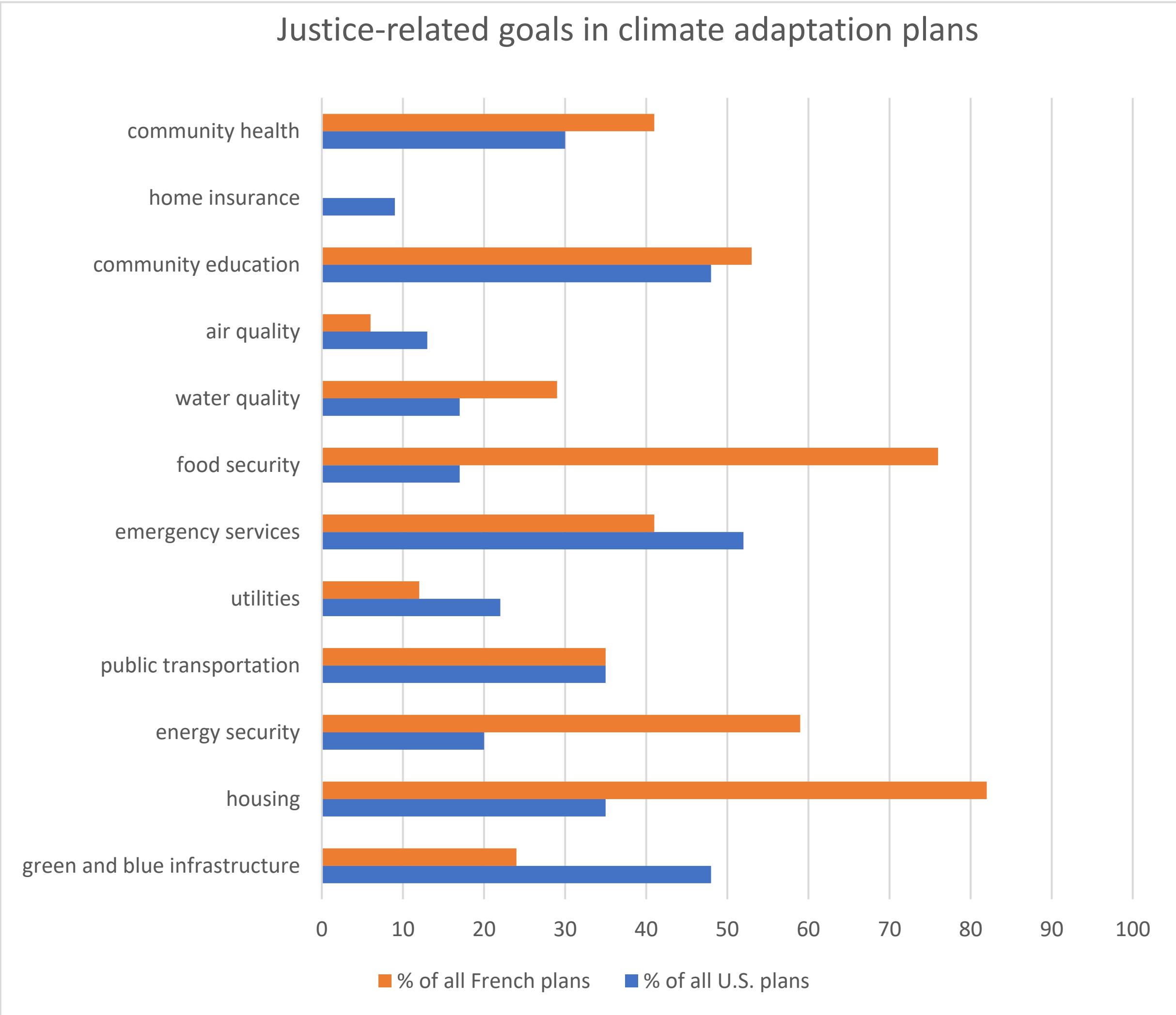


Figure 2. Justice-related goals in various domains of climate adaptation plans in the U.S. and French plans.

To monitor the implementation of these and other climate adaptation objectives, planners need accurate local data and tools to assess patterns of existing vulnerabilities, develop plausible scenarios, and formulate equitable adaptation strategies. For example, goals for equitable access to emergency response services related to weather extremes and hazards appear in 52% of U.S. and 41% of French plans. Yet, in both countries, it is apparent that factors such as race and ethnicity matter when it comes to the provision of governmental assistance [25,127]. "Years after Katrina, it is clear that the slow and incompetent emergency response was a disaster that overshadowed the deadly storm itself, and while Katrina brought governmental racial injustice to the forefront, this disparity has been affecting African American communities long before the storm. For decades, African Americans and other people of color have borne disproportionate environmental burdens—from pollution and poorly maintained neighborhoods to unsafe drug testing and lead poisoning—and for decades government regulators have largely ignored these injustices" [24]. To address these injustices block-by-block and neighborhood-by-neighborhood, climate adaptation strategies must rely on accurate information and be driven by fair planning policies [128,129].

Although 52% and 48% of French and U.S. plans, respectively, formulate adaptation goals related to inclusive community education and access to climate change information, they rarely contain specific metrics which could help track their implementation. For example, such goals may include communication of climate data in more diverse and accessible formats, such as community workshops, flyers, and brochures translated into

Spanish and other languages of predominant immigrant communities (in the U.S.), climate festivals, informal education and citizens science projects, and other community education programs and events.

The majority (76%) of French plans address justice in their food security adaptation goals, focusing on support of local agriculture, especially sustainably grown and organic, and local food sourcing for school cafeterias and pre-schools. Such an approach is multifaceted and pragmatic—to reduce carbon emissions from agriculture and food transportation, to support local agricultural markets, and provide children with nutritious, sustainably grown food.

Justice-centered adaptation strategies related to housing focus on energy efficiency and affordability of residential heating and cooling (in the U.S.) for low-income households and energy conservation with more efficient building materials, insulation, and sustainable design. Bridging climate change adaptation, community resilience, and GHG mitigation goals, 82% of French plans and 35% of American plans set specific goals for the housing sector aiming to reduce the share of energy expenditure in household budgets and improve energy conservation. Fifty-nine percent (59%) of French and 30% of U.S. plans also mention specific energy security measures, such as for example, the development of community solar projects and local microgrids. There is some inevitable overlap between equity-related objectives in utilities infrastructure and housing sectors, causing double counting of adaptation measures in these domains.

Institutional studies about social justice in the housing sector are also linked to the cost of public transportation, particularly in urban areas [130]. However, very few plans state objectives for free or otherwise subsidized transportation to improve mobility options for their less well-off populations. Adaptation objectives calling for equitable access to green and blue infrastructure and ecosystem benefits appear in 48% and 24% of U.S. and French plans, respectively. Examples of such strategies in the U.S. plans include urban afforestation and wildfire management measures, flood risk management through the river valley and coastal restoration; green infrastructure development, such as green roofs, green walls, rain gardens, and bioswales, collectively known as Nature-Based Solutions (NBS). In French climate plans, ecosystem-based adaptation strategies are mostly limited to the preservation of or creation of green spaces in urban areas. Nevertheless, the new National Strategy for Climate Adaptation Planning in France has prioritized nature-based climate solutions. As explored in detail by Pathak and others [131] (this issue), the implementation and monitoring of NBS require local-scale ecological data (such as soils, hydrology, microclimate, indigenous, endangered, and culturally significant species), integrated with climate services and tools.

Only 41% of French and 30% of American plans in our sample set goals related to climate adaptation measures supporting community health, such as extreme weather preparedness, extreme heat preparedness, and prevention of water-borne and vector-borne infections. Clearly, adequate planning tools, data integration, and collaboration between local health departments and planners are urgently needed to address the impacts of climate change on community health. Insufficient attention to public health in municipal climate adaptation planning has been reported in other studies. For example, the recent analysis of climate adaptation plans of 22 large cities in 14 countries, including 16 cities in high-income countries [132] indicated that even "highly health-adaptive large cities report fairly modest public health engagement in climate adaptation plans, and very few seem to have integrated a health perspective across thematic or sectoral climate adaptation priorities" (p.14).

Air quality is a key determinant of community health and is directly linked to temperature changes. Yet only 13% of U.S. and 6% of French plans set any justice-focused targets for air quality. Numerous studies indicate that racial and ethnic minorities and low-income people both in the United States [133] and France [127] are being disproportionally exposed to higher levels of air pollution. Ozone- and fine particle-related mortalities are expected to increase due to climate change, especially affecting vulnerable populations [134]. One of the key challenges for equitable planning is the lack of readily available large-scale monitoring data raising public awareness about glaring spatial correlations between environmental pollution, health, income, and race. Climate services need to be designed to uncover these existing spatial relationships between climate vulnerability and institutional racism, which continue to be rooted in unfair practices in urban planning. However, government regulatory agencies, such as the United States Environmental Protection Agency (EPA), the European Environment Agency (EEA), and the French Central Laboratory for Air Quality Monitoring (LCSQA), operate air quality monitoring networks of fixed monitoring stations that focus on assessing background levels in relatively large regions, grossly neglecting variabilities at a higher spatial resolution. Air pollution can be as much as eight times higher at one end of a city block than the other, according to the Environmental Defense Fund [135]. Local action requires local-scale data, integrating micro-level community-operated air monitoring networks, such as, for instance, Just Air Solutions, who, in partnership with the University of Michigan, is working directly with low-income communities in Detroit and Grand Rapids, MI on neighborhood-scale mapping, monitoring, and data visualization using ground sensors and GIS [136]. Another example of monitoring spatial inequalities in air quality at a high spatial resolution includes mapping projects by Institut Ecocitoyen Pour La Connaissance de Pollution [137] based in Fos-sur-Mer in France, monitoring communities exposed to air, water, and ecosystem pollution associated with industrial zones [138].

Similarly, only a handful of plans in our sample adopt a justice-related lens in addressing the vulnerability of their water resources. Adaptation goals targeting water shortage and water quality are typically generalized for the entire municipality. Although water supply in both countries is generally considered well-managed and safe, it presents problems associated with inequality in the distribution of water resources across different regions and unhealthy drinking water quality, which are likely to be exacerbated by climate change. Water quality problems are more likely in smaller, minority, and low-income communities that are socially, economically, and politically disempowered [139]. The recent drought episodes in France have prompted the government to develop guidelines for water prioritization [140], such as irrigation, swimming pools, and others, which raise many questions about equity, for example, irrigation of private golf courses at the expense of public green spaces in underprivileged communities [141]. Planning decisions based on transparent data would also require improved mapping and monitoring systems integrating water quality and allocation data.

As risks to hazards caused by the effects of climate change continue to increase, the current approaches to spreading financial responsibility need to be re-evaluated. Equitable access to home insurance appears to be the least represented sector in our sample of plans. Public–private insurance programs, however, could play an important role in managing the cost of adaptation and hazard mitigation measures. This would also require more sophisticated climate services for insurance companies to anticipate how their market will evolve in response to climate change, and specifically to provide risk modeling expertise, capital market solutions, actuarial services, and reinsurance design [142]. The U.S. National Flood Insurance Program (NFIP) managed by FEMA and delivered to the public by a network of more than 50 insurance companies and the NFIP Direct [143] plays an important role in reducing climate-related losses. Some increasingly important strategies used by the NFIP include mandatory flood insurance, insurance rate subsidization, and public–private cooperation to prevent the withdrawal of private insurers from high-risk areas.

3.3. Stakeholders' Role in Knowledge Development

While professional city planners and government officials lead local climate adaptation planning in both countries, many other groups participate in various stages of climate adaptation planning and co-creation of relevant information, methodologies, and tools (Figure 3). Municipalities in the U.S. appear to involve broader coalitions of stakeholders with local citizens (78%), environmental and climate advocacy groups (70%), academic institutions (65%), local businesses (61%), and private consulting firms (57%) being the most prominent participants. French plans more frequently involve local businesses (76%), followed by local citizens (53%), and environmental and climate advocacy groups (47%). The degree of stakeholder participation varies from attending community workshops and responding to local surveys to active engagement in data collection, community-based research, and other forms of direct and indirect contribution to adaptation plans and, increasingly, co-production and dissemination of information.

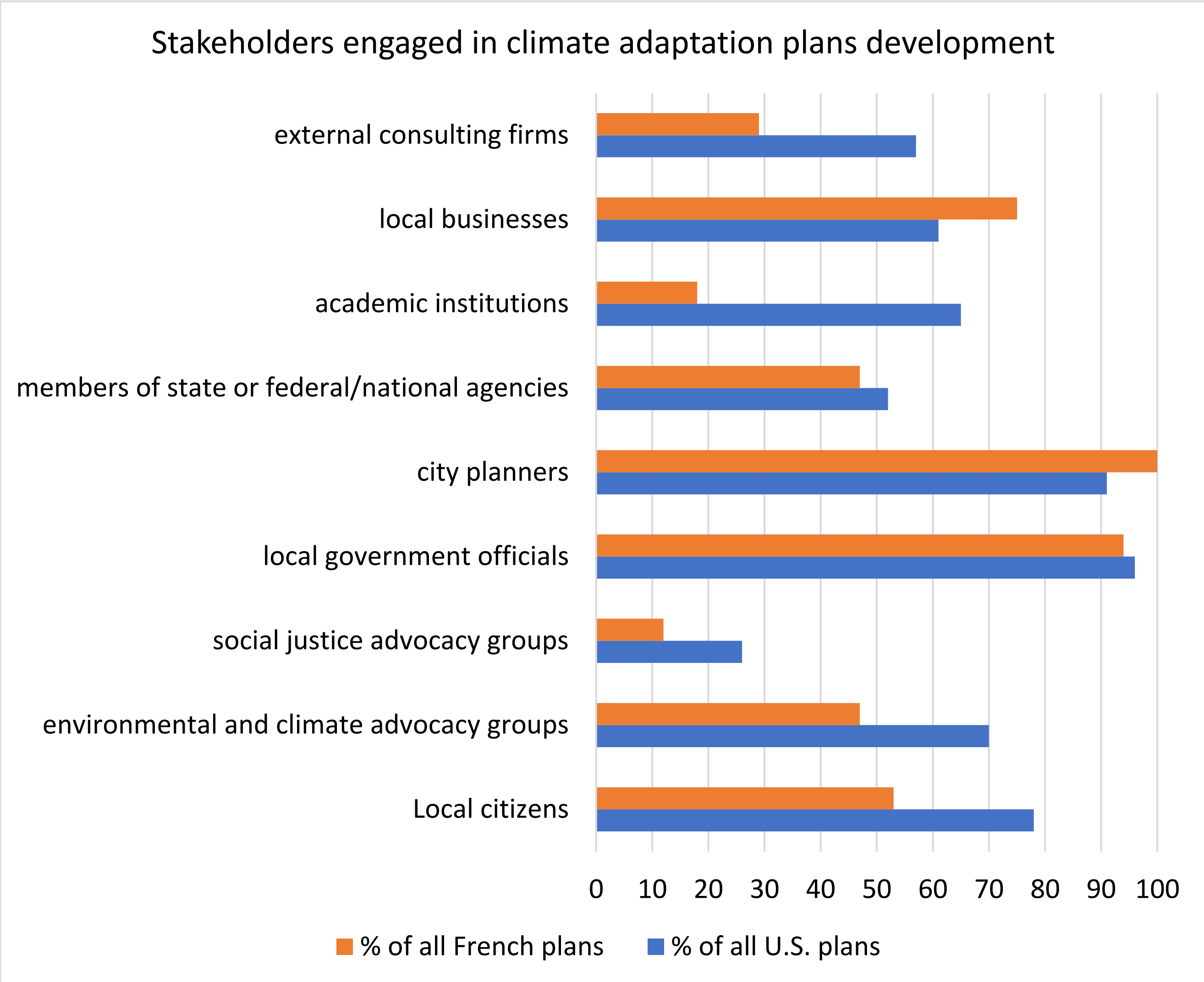


Figure 3. Categories of stakeholders involved in development of climate adaptation plans in the U.S. and France.

Although most climate adaptation planning methodologies recommend that municipalities engage community members in their vulnerability assessments and climate adaptation planning, opportunities for meaningful engagement of local citizens and especially vulnerable groups are quite low. One possible reason for this may be the lack of inclusive user-friendly collaborative engines tailored to non-expert participants, connecting local communities with relevant climate services and tools. A promising example of such a platform outside of our study areas is the Climate Just platform in the UK [144], connecting users and producers through high-resolution mapping of community vulnerability to climate change. Involvement of broad coalitions of various groups of stakeholders including citizens, schools, universities, environmental organizations, and private firms in the co-creation and analysis of knowledge is possibly the only realistic way to bridge the gap between the national and state-scale data providers and the city-scale and neighborhood-scale data needs. In this context, citizen science and collaborative crowdsourcing platforms have great potential for data collection, dissemination, and social participation [11,145]. By being involved in local citizen science projects, people value their role as being a part of the solution and become active contributors to climate services. Studies in the United States, France, and other countries suggest that data co-production not only can provide local-scale information for early warning and climate adaptation planning but also build community trust and support for climate policies [122,146].

Our analysis has several limitations. Although rigorous and formal, it is nevertheless based on a small sample of 40 cities and is meant to provide examples of information produced and used in climate adaptation planning. The results should not be extrapolated to generalize patterns and trends of climate adaptation planning. The list of municipalities used as case studies in our study is not exhaustive and is meant to provide insights from the two different national models. It should be noted that a priori French plans in our sample are more representative than their U.S. counterparts. Climate plans, including both climate change mitigation and adaptation components, are now required in France for all municipalities with populations of more than 20,000 people. There are now 307 urban and rural municipalities of various sizes in France that are following this national requirement, representing about one-quarter of French municipalities, with most of them being relatively large cities [33]. Even though many of the U.S. plans have been enabled and supported by federal policies [147], they are voluntary, driven by local and state circumstances and initiatives, and are less typical for the entire nation.

4. Conclusions

The planning, implementation, and monitoring of climate adaptation strategies rely on a broad range of constantly evolving multidisciplinary spatial data, generated at various scales. While traditional climate services provide useful background information for generalized long-term climate preparedness, they still offer minimal, if any, social, economic, and environmental data, typically being limited to climate data trends and scenarios.

Municipalities face numerous challenges in developing relevant methodologies, keeping up with scholarly literature, and obtaining adequate information for their climate adaptation planning efforts, which may result in the low quality of plans and mediocre implementation. Small municipalities have especially limited technological, human, and financial capacity. In France, municipalities receive significant support from the national agency overseeing local climate adaptation planning—ADEME, while in the U.S., many climate adaptation plans of small cities have been developed in partnership with local university partners through various grants. Despite these major differences, we have identified several major challenges hindering effective local climate adaptation planning in both countries and possibly worldwide.

Methodological challenges. Although numerous methodological resources for local governments have evolved during the past ten years, including brochures, toolkits, and clearinghouses featuring examples of existing adaptation plans, sorting through them in search of clear guidelines could be an insurmountable task of its own. In the absence of national and international standards for vulnerability assessment, municipalities adopt diverse methodological frameworks, definitions, and protocols, or skip the assessment altogether. Such conceptual fragmentation presents a major challenge for long-term monitoring, comparison, and data sharing among the cities. In many ways, such methodological ambiguity mirrors the continuous rift between adaptation planning and risk assessment communities in the scholarly literature [105,109,125]. The re-conceptualization of "vulnerability", introduced in the IPCC SREX and the Working Group Two Fifth Assessment Report has not been well received and provoked a split in the scientific community [109]. The most recent IPCC Sixth Assessment Report [107] further uses the concept of risk of the potential adverse impacts of, and response options to, climate change, treating exposure as a precondition rather than a dimension of vulnerability. Many vulnerability researchers, however, argue that treating exposure as a precondition of vulnerability or completely disassociating biophysical contexts from vulnerability limits the analysis of differential vulnerability caused by differences in biophysical components associated with geographic location, which can influence both the sensitivity and adaptive capacity of a system [125]. Most institutional guidelines including the ADEME methodologies used in France are based on the over twenty-year-old framework of the IPCC Third Assessment Report [126]. The simplicity and applicability of this framework made it popular with climate adaptation practitioners.

Ideological challenges. In the absence of methodological requirements to formulate adaptation objectives targeting climate justice, municipalities rarely do so. Many sectors of adaptation planning, such as community health, transportation, air quality, water quality, and many others are systematically overlooked in both countries. Even disaster emergency planning, where a focus on equity comes most frequently as a top priority, is absent in 48% of the U.S. and 69% of French plans. Equity in housing and food security adaptation is grossly overlooked in U.S. plans. Equitable access to green infrastructure and ecosystem services is mentioned in less than one-quarter of French plans and only 48% of U.S. plans. Even when such objectives are formulated, implementation strategies are often vague, lacking quantitative metrics for monitoring and evaluation. Further research is necessary to understand if these shortcomings are caused by local political ideologies, outdated methodologies, lack of adequate data, lack of involvement of vulnerable stakeholders, or all the above.

Data quality challenges. Adaptation planning and implementation monitoring require acquisition, analyses, and timely interpretation of high-quality multi-disciplinary data of relevant spatial and temporal resolutions, integrated into user-friendly formats, understandable for planners and the public. This includes not only macro-, meso-, and micro-climatological data but also agroecological, hydrological, demographic, cultural, economic, community health, zoning, land use, and other information. While many interesting high-quality products have been developed by academic and private data providers, they are not typically integrated with each other, are often hard to locate, and are rarely directly accessible to local planning departments, especially in small municipalities. Local air pollution, water quality, soil contamination, food security, community health, socio-economic, and demographic data, necessary to reveal their spatial correlations, are rarely available at the neighborhood and census-block scale.

Community connection challenges. Collection, analysis, and timely interpretation of relevant information require active community participation, especially at the scale of municipalities. National agencies and large for-profit data providers are unlikely to be able to fulfill these needs. Adaptation planning requires information, which is constantly evolving, relevant, local, transparent, open-access, and collected at the block or even household scale. We need active, truly diverse, and inclusive networks of local stakeholders engaging schools, universities, private and public organizations, community groups, and volunteers in the co-production of data, including local stories and indigenous knowledge, to inform collective co-construction of climate adaptation strategies.

We draw several recommendations for climate adaptation researchers and decision makers:

(a) Municipalities need flexible, user-friendly, and reliable tools for comprehensive vulnerability assessment, mapping, and monitoring, informed by the up-to-date body of knowledge and best practices around the world, and relevant to their geographical context. Many currently existing products are based on outdated literature and offer rigid step-by-step guidelines, rather than interactive analytical tools. Cities need the best common standards, which are currently lacking, but not necessarily common data sources or guidelines.

(b) Centralized approaches to data monitoring for climate adaptation planning often fail to provide information at relevant temporal and spatial scales. Produced by different agencies and groups of experts, these databases are often hard to integrate and downscale. Decentralized interdisciplinary monitoring networks equipped with digital applications allowing local citizens to engage in knowledge production may offer promising alternatives.

(c) Climate-adaptation design tools for local governments should prioritize climate justice in all adaptation contexts and sectors. GIS-based online mapping tools and mobile applications are very helpful in visualization and analysis of spatial correlations between income, race, environmental justice issues, and various dimensions of vulnerability to climate impacts, helping to inform difficult conversations about resource allocations in climate adaptation planning.

(d) Long-term funding programs are necessary to provide financial and other resources and incentives for stakeholders' collaboration and community engagement in local knowledge co-production. Funding agencies should prioritize active local and regional partnerships involving academic institutions, schools, advocacy groups, local businesses, and especially citizens and organizations representing the most vulnerable communities. Funding programs that prioritize mainstreaming climate adaptations into neighborhood revitalization, food-security, community wellness, environmental education, and citizen-science projects should be designed to support long-term partnerships among all local actors.

(e) Climate education networks, local working groups, and other boundary organizations connecting experts and non-experts would play an increasingly important role in merging community-based education, scientific research, climate action, and co-design of digital technologies, tools, and data for local climate adaptation planning.

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