



# 3 Challenges, 3 Errors, and 3 Solutions to Integrate Frontline Communities in Climate Change Policy and Research: Lessons From California

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Frontline communities of California experience disproportionate social, economic, and environmental injustices, and climate change is exacerbating the root causes of inequity in those areas. Yet, climate adaptation and mitigation strategies often fail to meaningfully address the experience of frontline community stakeholders. Here, we present three challenges, three errors, and three solutions to better integrate frontline communities' needs in climate change research and to create more impactful policies. We base our perspective on our collective firsthand experiences and on scholarship to bridge local knowledge with hydroclimatic research and policymaking. Unawareness of local priorities (Challenge 1) is a consequence of Ignoring local knowledge (Error 1) that can be, in part, resolved with Information exchange and expansion of community-based participatory research (Solution 1). Unequal access to natural resources (Challenge 2) is often due to Top-down decision making (Error 2), but Buffer zones for environmental protection, green areas, air quality, and water security can help achieve environmental justice (Solution 2). Unequal access to public services (Challenge 3) is a historical issue that persists because of System abuse and tokenism (Error 3), and it may be partially resolved with Multi-benefit projects to create socioeconomic and environmental opportunities within frontline communities that include positive externalities for other stakeholders and public

service improvements (Solution 3). The path forward in climate change policy decision-making must be grounded in collaboration with frontline community members and practitioners trained in working with vulnerable stakeholders. Addressing co-occurring inequities exacerbated by climate change requires transdisciplinary efforts to identify technical, policy, and engineering solutions.

**Keywords:** local knowledge, multi-benefit projects, buffer zones, community-based research, disadvantaged communities, environmental justice, climate justice, co-production

## INTRODUCTION

Frontline communities experience the compound effects of social, economic, and environmental injustices. Climate change is exacerbating the root causes of injustice in those areas, yet adaptation and mitigation strategies often fail to address the knowledge of frontline community stakeholders. Here we present three challenges, three errors, and three solutions to better integrate the needs and perspectives of frontline communities into climate change adaptation and mitigation strategies. The challenges refer to some of the most pressing current and inherited circumstances experienced by frontline communities. The errors inhibit the resolution of one or more challenges, stem from actions of policymakers and academics, and are exacerbated by the lack of public and media representation of frontline communities. The solutions intend to resolve the challenges by exploring possibilities to integrate policy and research with landowners, industry, and the broader society toward achieving environmental justice and just transition. All challenges, errors, and solutions are interconnected, as the issues experienced in frontline communities are compounding and greater than the sum of their parts (**Table 1**).

Our perspective is grounded in our collective firsthand experiences working with, living in, and serving frontline communities for years, and on the climate change and environmental justice scholarship. We use the case of the San Joaquin Valley in California, which is one of the most socially and environmentally vulnerable regions in the United States, as an example of the issues surrounding climate change and vulnerable communities, and where its residents (the present authors among them) are already experiencing climate change impacts to their livelihood. We are a group of academics, community leaders, policymakers, non-profit organizations staff, and educators who have been collaborating for several years among us and with many frontline communities. This work is a summary of our shared vision of the necessary foundation to bridge local knowledge with hydroclimatic research and policymaking to improve the outcomes of climate change decisions oriented to serve frontline communities.

## BACKGROUND

The lack of representation of frontline communities in climate change research, adaptation strategies, and mitigation policies has deep historical roots in California. For decades,

the most vulnerable communities of California have been subjected to unjust policies founded upon racism, lack of awareness, and underrepresentation, especially against socioeconomically depressed rural communities (OEHHA, 2017; Fernandez-Bou et al., 2021; Flores-Landeros et al., 2021). The structural discrimination in the San Joaquin Valley has created some of the worst environmental conditions experienced in any rural region in the United States (Huang and London, 2012).

Over a century ago, when agriculture started to expand in the San Joaquin Valley after the genocide of Native Americans (Johnston-Dodds and Burton, 2002; Madley, 2016), African Americans fled the oppressive Jim Crow Laws that imposed anti-Black racial segregation in Southern United States just to find similar racial discrimination in California. Minority farmworkers and low-income families were excluded from urban areas and were forced to create rural communities that lacked government and public investment (Eissinger, 2009, 2017). When other industries were recognized in the National Labor Relations Act of 1935, farmworkers (and domestic workers) were excluded from obtaining the same rights in what historians identify as a ripple effect of slavery (Perea, 2010). Then the demographics of California changed, Hispanics inherited the role of underpaid farmworkers (Martin, 2002) while Southeast Asian refugee farmers were marginalized (Sowerwine et al., 2015), and other levels of complexity such as legal residence status, farmland access, and language barriers aggravated the situation (Thao et al., 2019).

Vulnerable communities are often located in areas with a disproportionately degraded environment and are more exposed to hydroclimatic hazards, such as extreme heat, droughts, and floods. The lack of awareness and representation in public discourse has contributed to policies that overlook low-income rural communities and to insufficient investments in fundamental local infrastructure and health services (Shanahan et al., 2008; Flegel et al., 2013; Bernacchi et al., 2020), leaving underserved communities with fewer resources to adapt to climate change. The San Joaquin Valley is the most valuable agricultural region in the United States (CDFA, 2020), and petroleum extraction in the south makes of California one of the largest oil and gas producers in the country. At the same time, parts of the San Joaquin Valley experience the worst air quality in the United States (American Lung Association, 2020) and hundreds of thousands of residents live without their Human Right to water (Pannu, 2012; Ores, 2019; London et al., 2021),

**TABLE 1** | Challenges, errors, and solutions to integrate California rural frontline communities into climate change adaptation and mitigation strategies.

Challenges	Errors	Solutions
<p><b>Unawareness of local priorities</b> Policymakers and scientists do not understand well the concerns in frontline communities, which causes faulty policies and understudied persisting local issues.</p>	<p><b>Ignoring local knowledge</b> Superiority complex and lack of interest by policymakers/scientists to find out firsthand local issues in frontline communities combined with media underrepresentation increase policy and research likelihood to fail.</p>	<p><b>Information exchange</b> Engaging community stakeholders in community-related projects and research promotes well-informed decisions that are more likely to succeed, and it creates inclusivity and a sense of belonging for community members.</p>
<p><b>Unequal access to natural resources</b> Frontline communities experience historical water insecurity, extremely low air quality, and lack of access to healthy green spaces; climate change is aggravating these circumstances.</p>	<p><b>Top-down decision making</b> Policymakers and scientists assume that they know what frontline communities need without ground-truthing their assumptions, especially regarding environmental justice, which leads to ineffective policies and irrelevant research</p>	<p><b>Buffer zones</b> In rural communities, a physical separation between agricultural lands and oil fields can improve water and air quality; buffer zones can be repurposed into activities with positive externalities for the communities and multi-benefit projects.</p>
<p><b>Unequal access to public services</b> Public services are a prerequisite for resilience and effective climate change adaptation and mitigation, including basic public infrastructure, healthcare, and socioeconomic opportunities that have been historically suppressed from frontline communities.</p>	<p><b>System abuse and tokenism</b> System abuse (for example, “inverse Robin Hood:” taking from the poor to give to the rich) and tokenism (using vulnerable stakeholders to benefit oneself) prevent frontline communities from benefiting of funding allocated to serve them. These practices benefit the project proponent far more than the intended beneficiary.</p>	<p><b>Multi-benefit projects</b> Innovative frameworks to manage common pool resources to reverse systemic injustice based on trust and participation among frontline communities, academia, society, nonprofit organizations, and governments. Land use repurposing can help achieve environmental and socioeconomic justice while promoting diverse income sources for farmers (solar energy, aquifer recharge, clean industry).</p>

*The challenges are current and inherited circumstances experienced by frontline communities. The errors inhibit the resolution of one or more challenges, stem from actions of policymakers and academics, and are exacerbated by the lack of public and media representation of frontline communities. The solutions intend to resolve the challenges by exploring possibilities to integrate policy and research with landowners, industry, and the broader society toward achieving environmental justice. All challenges, errors, and solutions are interconnected, as the effects of the issues experienced in frontline communities are compounding and greater than the sum of their parts (Table 1).*

while climate change increases their environmental vulnerability and risk (Ray et al., 2020).

Still, the most persistent problems arise from legacies of injustice such as racism, discrimination, lack of opportunities, and lack of political representation (Fernandez-Bou et al., 2021). These conditions are exacerbated by climate change (Phillips et al., 2020) and inhibit efforts to address the climate crisis. As California experiences increasingly devastating impacts of climate change, the state is at risk of perpetuating historical inequities in access to resources between wealthy and low-income communities. California has invested admirable efforts to identify these frontline communities, calling them “disadvantaged communities”<sup>1</sup> and creating the state-of-the-art

<sup>1</sup>CalEnviroScreen 3.0 defines a disadvantaged community as a census tract that performs in the 75th percentile or worse in a set of 20 socioeconomic and environmental indicators. This score has two parts: (1) pollution burden, subdivided in exposures (ozone, particulate matter 2.5 μm, diesel emissions, contaminants in drinking water, pesticides, toxic releases, traffic density; this component represents 33.3% of the final score) and environmental effects (cleanup sites, groundwater threats, hazardous waste, impaired water bodies, and solid waste sites; this component represents 16.7% of the final score), and (2) population characteristics, subdivided in sensitive populations (asthma, cardiovascular disease, and low weight at birth; this component represents 25% of the final score) and socioeconomic factors (education, housing burden, linguistic isolation, poverty, and unemployment; this component represents 25% of the final score). Each indicator has a percentile for each census tract compared with the rest of the state, and the weighted indicators are averaged to calculate the CalEnviroScreen score for each census tract. A census tract receives the disadvantaged status when its score is between the 75th percentile and the 100th

percentile. An alternative tool is used by the California Department of Water Resources, defining disadvantaged communities as places with household income less than 80% of the median household income of California.

tool CalEnviroScreen (OEHHA, 2017, 2021). However, to date, CalEnviroScreen lacks climate change indicators. Identifying frontline communities is the first step, but much more work is needed. Here we share our perspective about the keys to develop beneficial climate change research and policies for frontline communities.

### 3 CHALLENGES

#### Challenge 1: Unawareness of Local Priorities

Rural frontline communities of California are underrepresented, understudied, and underserved, and there is a gap between their self-identified concerns/priorities and their quantitative representation in media, science, and legislation (Fernandez-Bou et al., 2021). Climate change policies and research are often developed with positive intentions to integrate environmental justice, but do not address the root sources of inequity (London et al., 2013).

**Inadequate identification and characterization** of rural frontline communities/stakeholders as disadvantaged complicates targeting climate change solutions and investment. Besides lacking climate change indicators, CalEnviroScreen uses census tracts as scale for identification, which is not

percentile. An alternative tool is used by the California Department of Water Resources, defining disadvantaged communities as places with household income less than 80% of the median household income of California.

well-suited for many rural areas of the San Joaquin Valley. A single census tract overlaying privileged communities may shadow disadvantaged ones (e.g., Tooleville). Similarly, small-scale disadvantaged farmers often rent land within wealthier census tracts, resulting in a mismatch between disadvantaged communities and disadvantaged farmers. CalEnviroScreen scoring also allows for good scores to counterweight for bad scores, which erases extreme vulnerabilities; for example, good traffic can compensate for harmful air quality and toxic water in a community (e.g., Arvin).

**Media underrepresentation** negatively affects scientific research and policymaking (Shanahan et al., 2008; Likens, 2010). Inadequate diversity of stakeholder representation in public climate change discourse may contribute to the exclusion of frontline communities from topics that affect them dramatically. For example, despite state-mandated efforts to engage frontline communities in groundwater sustainability planning under climate change, public communications largely underserved non-English speakers (Bernacchi et al., 2020).

**Insufficient understanding of local-level climate change priorities** stems from a lack of transdisciplinary literature addressing local stakeholders' perspectives. Community-inclusive research takes more time, requires a different skillset, and is not incentivized by academic institutions (Balazs and Morello-Frosch, 2013; Duran et al., 2013; Johnson and Zentella, 2017).

## Challenge 2: Unequal Access to Natural Resources

Frontline communities need climate change adaptation strategies to preserve natural resources (water, air, and soil), but they face a history of government and industry negligence that created unequal access to natural resources, especially in rural unincorporated communities. As climate change brings longer and more extensive droughts and concentrates precipitation in already-wet winter months (Persad et al., 2020), rural frontline communities of California are facing dry wells (Pauloo et al., 2020) and higher concentrations of toxic chemicals (Smith et al., 2018). Dry periods also lead to more dust and airborne particulate matter due to inadequate agricultural soil health, increased wildfire risk (Crockett and Westerling, 2018), and degraded air quality for farmworkers and rural communities.

**Water insecurity** is a persistent inequity in many rural frontline communities of the San Joaquin Valley (London et al., 2021). However, its origins can be different; for example, water insecurity can be related to poor water quality (even toxic water with heavy metals and pathogens), wells going dry, lack of connection to a reliable system, or a combination of factors. Defective access to safe drinking water (with greater impacts from exposure to contaminants and burdensome expenses in bottled water in marginalized communities) has been widely documented (Balazs and Ray, 2014; Ranganathan and Balazs, 2015; Allaire et al., 2018; Dobbin and Lubell, 2019; Dobbin, 2020; Fernandez-Bou et al., 2021; Tariqi and Naughton, 2021), as well as the lingering impacts from hydroclimatic hazards, such as wildfires and droughts (Greene, 2018). Frontline communities,

rural domestic well users, and small-scale farms operated by disadvantaged farmers are at higher risk of losing their wells during droughts (Bostic et al., 2020; Méndez-Barrientos et al., 2020; Pauloo et al., 2020).

**Air quality issues** translate into poorer health and elevated risk of premature deaths disproportionately affecting Black and Brown communities (Hall et al., 2008). Air quality can be hazardous because of emissions from transportation, heavy industry, agriculture (pesticides, dust, diesel emissions from irrigation pumps), and fires (managed and wildfires; SJV Air Pollution Control District, 2020), and impacts are more severe for residents near polluting activities, which are more often located in lower-income communities (e.g., valley fever).

**Green areas for recreation and wildlife corridors are scarce** and beyond reach for families without private transportation, especially as public transportation is insufficient. Access to green spaces and contact with nature reduce stress, protect from heat, and enhance health (Ekkel and de Vries, 2017; Allen et al., 2021).

## Challenge 3: Unequal Access to Public Services

Public services are a prerequisite for effective climate change adaptation and mitigation. However, systemwide structural injustice prevents certain communities from having access to such essential services as basic infrastructure, socioeconomic opportunities, and education, that are a critical foundation for resilience to climate change.

**Lack of basic infrastructure** such as drinking water systems, sewage, sidewalks, streetlights, paved roads, public transportation, green areas, benches, and grocery stores. Environmental sustainability in communities with less infrastructure is more difficult to attain than in wealthier cities (Lubell et al., 2009; Ulibarri et al., 2017), especially in rural unincorporated communities (London et al., 2021). Climate change will increase damage to current infrastructure, worsening living conditions where essential infrastructure is lacking.

**Socioeconomic injustice**, unequal access to digital education, racism, discrimination, multi-family households, gentrification, and lack of political representation (Flores-Landeros et al., 2021). Low-income communities often lack adequate housing conditions to face increasing weather extremes driven by climate change (e.g., air conditioning or insulation). Disadvantaged farmers<sup>2</sup> of the San Joaquin Valley (e.g., some small family-owned and minority farmers) experience age, educational, and language barriers and have more limited resources for farm improvements (Thao et al., 2019).

**Healthcare is worryingly underfunded** in California's rural frontline communities (PHA, 2020), which are among the most impacted by the coronavirus pandemic (Hatef et al., 2020). Access to healthcare is even more compromised for undocumented

<sup>2</sup>“Disadvantaged farmers” is an umbrella term that refers to socially disadvantaged farmers and ranchers according to the California Assembly Bill 1348 of 2017. “Socially disadvantaged groups” refers to groups whose members have historically experienced racial, ethnic, or gender discrimination, including African Americans, Native Indians, Alaskan Natives, Hispanics, Asian Americans, Native Hawaiians, and Pacific Islanders. In California, most disadvantaged farmers are normally Hispanics and Southeast Asians.

residents and tribal communities (Kelch, 2015; Brunton and Smedley, 2019). Many residents need to go to Mexico for low-cost surgeries, technical dental work, and other lingering health challenges. The lack of health coverage has forced a culture of “garage” doctors and dentists throughout the San Joaquin Valley, and the COVID-19 crisis has further exposed the fragile healthcare system.

### 3 ERRORS

#### Error 1: Ignoring Local Knowledge

Excluding local experts and knowledge can contribute to inadequate planning to address environmental justice in climate change strategies, and it can prevent stakeholder involvement in essential decisions and project development. Studies that do not include, employ, and compensate local perspectives are less reliable.

**Local knowledge is disregarded** by science and policymakers in favor of Westernized techno-scientific perspectives to address environmental problems ignoring local and indigenous wisdom. This paternalistic approach stems from a superiority complex and considers the locals as “in need of help,” focusing on what the community is supposedly lacking or “doing wrong,” and neglecting local knowledge, assets, and strengths.

**Nuances and specific local issues are overlooked** when local knowledge about social and environmental problems are not included. Many environmental problems are locally unique and require community engagement and participation to accurately define solutions that improve residents’ lives (Fernandez-Bou et al., 2021).

**Projects fail when local perspectives are not included** in research and policy design. Attempts to resolve environmental injustice are limited by the available (scientific) knowledge, and the most pressing local issues may be different than policymakers’ and researchers’ assumptions. For example, the community of Lanare (Fresno County) received a \$1.3 million water treatment plant to remove arsenic from their drinking water that went offline after a few months because it was too expensive for them to maintain (Ores, 2019).

#### Error 2: Top-Down Decision Making

Power disparities grant decision-making power to scientists and policymakers as the only experts, perpetuating a *status quo* that prevents communities from meaningful involvement in policy development and that leads to ineffective climate change policies that are not tailored to address local needs and resource gaps.

**Top-down decision making promotes uneven power relations**, impeding well-informed bottom-up, effective research and policy when decision-makers imagine that they know what frontline communities need without ground-truthing their assumptions and believe that those without power lack the capability to contribute (Sadd et al., 2014). This often occurs through unilateral research/policy formulation and suppression of open discussion.

**Limited community and local-level autonomy** and decision-making power involving projects and policies that directly affect them promotes relations of dependency and welfare. Top-down

regulatory actions can have unintended consequences when communities are not involved in community-related decision-making processes (Dahlquist-Willard and Gazula, 2017; Simon, 2020). Policies that promote local and community engagement without providing decision power to resolve environmental inequities perpetuate a cycle of disempowerment and poor quality of life.

#### Error 3: System Abuse and Tokenism

System abuse or “inverse Robin Hood” (taking from the poor to give to the rich) and tokenism perpetuate the issues experienced by frontline communities that should be benefiting from climate change adaptation or mitigation strategies yet rarely gain from the funding allocated to serve them. These practices benefit the project proponent far more than the intended beneficiary. For example, California requires inclusion of frontline communities in Groundwater Sustainability Plans development, but they are often excluded by more powerful stakeholders who (willingly or not) prevent them from participating by using such approaches as English-only notifications in non-English-speaking communities and scheduling meetings at times or in places that community members cannot attend (Dobbin and Lubell, 2019; Dobbin, 2020).

**Intentions are sometimes more harmful than helpful** if self-interest, privilege, and biases are not addressed from the beginning. Researchers are pressed to articulate equity benefits for underserved communities to promote their proposals, but sometimes unrelated third parties obtain the largest gains. Proposed beneficial impacts often rely on future potential employment or subjective environmental benefits with nearly no net benefit for underserved communities (Cushing et al., 2018; Kaswan, 2019). Funding agencies can prevent and sanction these practices by assessing project outcomes.

**Tokenism** uses (hiring, collaborating, and mentoring) people from minorities or disadvantaged backgrounds to benefit oneself without creating an environment for them to thrive, contributing to oppression of marginalized groups. Performative partnerships with community stakeholders claim inclusiveness without dedicating sufficient resources or community members.

### 3 SOLUTIONS

#### Solution 1: Information Exchange

Information is power: a two-way flow of information between frontline community stakeholders and scientists can co-create partnerships for targeted education, to develop community-based projects, and to apply for funding and programs that reduce equity gaps and increase climate change resilience. It is also essential to maintain the relationship with the communities after projects are implemented. Information must be accessible to the communities in their primary languages.

**Promote community-based participatory research, co-production, and community-science** to provide a sense of responsibility and respect, to empower communities to advocate for themselves (Durose et al., 2012; Hibbett et al., 2020; Tauginiene et al., 2020), and to locally lead community development strategies (Lung-Amam and Dawkins, 2020). Local

and indigenous people have deep cultural and environmental understanding of their lands and communities. Community engagement must be done with mindfulness to avoid projecting supremacist attitudes such as “needing to be educated,” and participants must be compensated for their work.

**Encourage community-led initiatives to address local perspectives.** Communication products can include educational guides about how inequities are exacerbated by climate change, and include ideas to adapt and increase resiliency (Ortiz-Partida et al., 2020).

**Expand lines of communication between media and local stakeholders** to increase coverage and representation of inequities in frontline communities. Media can depict the reality in frontline communities, corroborate their knowledge, and better represent the nuances of the issues that they experience to increase awareness and inspire research and policy.

**Eliminate paternalism** by promoting inclusive conversations among local stakeholders, researchers, and policymakers, and by sharing decision-making power with those whose lives are most affected by the decisions.

## Solution 2: Buffer Zones

Buffer zones are physical separation areas that can provide environmental protection around rural frontline communities by preserving community aquifers from agricultural overextraction and pollution, and by decreasing pesticide drift and dust exposure. Buffers can bring environmental justice and socioeconomic opportunities to mitigate the intersectional impacts of climate change while improving human health and local economy. Removing unsustainable agriculture from inside frontline communities can reduce undesirable impacts too. To maximize multiple benefits, it is necessary to include all the involved stakeholders in the planning and implementation.

**Local water security** for communities reliant on groundwater requires across-sector efforts such as securing funding for new wells or maintenance programs, improving representation in water regulation implementation, and preventing deeper industrial wells to withdraw the water from the aquifer underneath the community (Mayzelle et al., 2015).

**Clean air**, reducing direct pesticide spray and drift from agriculture over communities (Gunier et al., 2017), toxic emissions from polluting industries such as fracking, and stench from cattle industry or waste processing plants. In California, pesticide regulation establishes a ¼ mile (400 m) distance restriction surrounding schools in rural areas to protect children from pesticide exposure (Department of Pesticide Regulation No. 16-004), and some cities that experience extremely low air quality such as Arvin have imposed broader setbacks restricting oil wells near residential areas (Ordinance No. 451, 2018).

**Parks and green space** serve as buffers from agricultural and industrial activities, provide recreational opportunities and mental health benefits (Lee, 2020), and can be used for habitat restoration (e.g., TNC, 2018).

## Solution 3: Multi-Benefit Projects

Multi-benefit projects represent new frameworks to manage common pool resources based on participation, communication,

and trust among frontline communities, academia, nonprofit organizations, society, and governments. Different actors have different perceptions of vulnerability and risk-aversion level, and these partnerships develop holistic bottom-up strategies for new socioeconomic and environmental opportunities, for climate change adaptation and mitigation, and for better policies in general.

**Land use repurposing to achieve environmental justice** can be profitable for multiple stakeholders while also bringing socioeconomic opportunities for frontline communities. Managed aquifer recharge projects (Flood-MAR) can improve water security in frontline communities, incentivize farmers, and increase groundwater reliability for agriculture and ecosystems (Bourque et al., 2019; Bryant et al., 2020; Marwaha et al., 2021; Ulibarri et al., 2021). Renewable energy can be combined with agriculture (e.g., agrivoltaic systems). Clean agribusiness (e.g., food processing with optimized water usage) can be implemented near frontline communities providing economic opportunities and facilitating local logistics, and public-private partnerships can build essential infrastructure to serve those new businesses and local communities. Green areas and wildlife corridors can help conservation efforts and bring incentives to landowners. There already are state incentives to favor this land use transformation (e.g., California Assembly Bill 327, 2013) for neighboring agricultural and industrial operations.

**Evaluation of projects in socio-ecological systems must go beyond economic performance.** A combination of engineering, natural science, and social science can provide tools and metrics to evaluate long-term multi-benefit projects. Assessments can include non-market attributes such as water and air quality, biodiversity, justice, equity, poverty, vulnerability, and health.

## DISCUSSION AND CONCLUSIONS

Researchers and policymakers interested in contributing to better living conditions in rural frontline communities often have an incomplete perspective of how to work with them or lack support from community-based organizations. Without community participation, climate change research and policies can be insufficient or even harmful. Understanding the nuances of the needs experienced by each community and addressing co-occurring inequities exacerbated by climate change merit transdisciplinary tools to find technical, social, and engineering solutions.

Frontline communities deserve to benefit from the implementation of just policies and also to contribute to their construction. Institutions crafting policy and research decisions to benefit frontline communities must engage in the learning process required to understand the real challenges that communities face and include community residents in policy development directly. Assuming what the communities want or need instead of learning it firsthand has led to unsatisfactory and insufficient results to improve living conditions in frontline communities.

A path to just climate change adaptation and mitigation strategies for frontline communities includes information

exchange among community stakeholders, scientists, media, and decision makers. Researchers and policymakers need to better understand the local nuances and priorities of each community and together address how climate change is exacerbating those issues. Providing platforms for inclusion and meaningful engagement where the communities can advocate for themselves will amplify their perspectives and knowledge, while increasing their representation in media, science, and policymaking.

The strategic implementation of diversified land uses in buffer zones surrounding frontline communities can provide increased local resilience to climate change benefitting socioeconomic, environmental, and public health outcomes. Multi-benefit projects integrating diverse perspectives and encouraging stakeholder participation can heighten recognition of the currently unsustainable use of natural resources that is exacerbated by climate change. Such projects must evaluate and prove benefits under climate change scenarios and serve to ameliorate impacts from projected hydroclimatic hazards in frontline communities. For frontline communities to thrive, addressing co-occurring inequities exacerbated by climate change requires transdisciplinary efforts to identify technical, policy, and engineering solutions that include community knowledge and continuous engagement.

## DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

## AUTHOR CONTRIBUTIONS

ASF-B and JPO-P: contributed with conceptualization, project administration, and writing—original draft. LC-R, CP, KD, VE, JR-F, CT, CH, AF, HF-L, MM, SC, SA, and EG: contributed with conceptualization and writing—original draft. AG, AA, CW, MC-M, ES, RD-W, LAB, and RD: contributed with writing—revision and editing. CN and JM-A: contributed with funding

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