



# Justice and injustice in “Modular, Adaptive and Decentralized” (MAD) water systems

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## ABSTRACT

Centralized water infrastructure is challenged by climate change, infrastructure degradation, underinvestment, and shifting water demands. In its place, scholars have argued for “Modular, Adaptive and Decentralized” (MAD) water systems. We critically interrogate the environmental injustices that produce, and may be reproduced through, MAD water systems. We focus on two key dynamics by which MAD systems emerge: “shoving-out” of, and “opting-out” from, centralized water systems. Using a justice-based framework, we synthesize three cases from Texas, California, and North Carolina, each illustrating how racial and socio-economic marginalization produce MAD water systems. We argue that identifying the structural and relational forces that drive “shove-out” and “opt-out” dynamics remains key for theorizing the enactment of MAD water systems.

## 1. Introduction

Globally, billions of people lack safe drinking water and sanitation facilities [1], and a staggering four billion people live in areas where they experience water scarcity for at least one month per year [2]. These statistics demonstrate centralized modern water infrastructure’s failed promise to address global water insecurities [35]. Specifically, the scale of water insecurities reflects the on-going exclusion and marginalization of billions of people from public and private centralized water systems (e.g., [6–14]). For those served by centralized water supply and distribution systems, the collective impacts of climate change, urban water demand, out-migration, fiscal austerity, underinvestment, and regressive burdens in water pricing, amongst other factors, undermine adequate and safe water provision (e.g., [10,15–23]). Climate change, in particular, carries risks for centralized water infrastructure [24], including physical damage, the inability to serve increasingly mobile

populations, and water quality decline associated with its complex ecological impacts. This paper explores the capacity of an emergent approach - modular, adaptive, and decentralized water systems or “MAD water” - to contribute to more just and equitable water provision. Here, we utilize a MAD water justice framework [25] to theorize justice and injustices focusing on three case studies from the United States (U.S.). These case studies illustrate factors that create or reinforce how different communities experience water injustices. While we acknowledge considerable research in the Global South has explored dynamics of (in) justice as it relates to decentralized water systems, our review focuses on related dynamics of MAD water systems in the U.S.

## 2. “MAD water”: A new convergence approach for water systems

Modular, adaptive, and decentralized water systems, or “MAD water,” is a novel approach to address water insecurity under a changing

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climate [24,25]. MAD water integrates social, environmental, and engineering sciences to address unmet needs and risks associated with centralized water systems [24]. As MAD water systems integrate social and engineered infrastructures, researchers use a convergence approach—problem-based research integrating disciplines, methods, and expertise [26]—to build this field of scholarship. Rather than proposing to reinvent water management, MAD water synthesizes and leverages existing evidence of successful non-networked, informal, hybrid, decentralized, patchwork, alternative, intermittent, heterogeneous, and cognate systems [27–46]. MAD water systems may be built around recent engineering advancements, such as nanotechnology-enabled water treatment [47] or ancient technologies, such as rain-water harvesting [48]. What these systems share is that they are: (1) designed for harvesting, treating, distributing, monitoring, and/or governing water or wastewater; (2) modular (fit-for-purpose and easily replicable); (3) adaptive (quickly deployed in response to needs); and/or (4) decentralized (localized, distributed, and dispersed) (see: [24,25]). Importantly, MAD water systems recognize that adaptive, modular, polycentric, and flexible water governance approaches can enhance water security and system resilience [20] (see: [49–51]).

While MAD water systems have often been seen as mere stopgap measures to avert water crises, some suggest that future water systems may integrate MAD technologies with older water systems to enhance system performance [52]. Yet theoretical and empirical evidence for how to integrate such social and engineered infrastructures is currently lacking. Even proponents of MAD water systems have argued that, without serious effort, such water systems will deepen existing inequities and injustices [24,25]. Building on the large and important literature that documents a range of water injustices, our paper represents an effort to seriously grapple with the dynamics that produce injustices in MAD water systems.

### 3. Shove-out and opt-out dynamics in MAD water systems

In MAD water systems, “opt-out” and “shove-out” dynamics are proposed to be key factors that create or amplify water injustices [25].<sup>1</sup> Opt-out dynamics happen when high-income residents or communities refuse to invest in centralized water systems that collectively serve diverse communities. These elite communities may then create or rely on their own small-scale MAD water systems. In another case, elites may build large-scale centralized water systems that marginalize and exclude smaller communities who are often lower-income communities of color. This results in shove-out dynamics, in which marginalized or low-income communities are forced to rely on non-networked sources or build their own small-scale MAD water systems, which are frequently underfunded, lack economies of scale, and are poorly performing. We consider both dynamics—shove-out and opt-out—in greater depth here.

Shove-out dynamics occur when less powerful communities are excluded from safe and sufficient centralized water provision [25]. Scholars have shown that regardless of income, white communities sacrifice economies of scale to avoid racial heterogeneity in their communities [54]. One well-documented example that supports racialized community segregation is municipal underbounding [55], a process through which low-income racialized groups are directly or indirectly excluded from city boundary creation or expansion (and with it, residential amenities, such as water service connections) [56]. Different from incorporated municipalities, which are legally recognized and are constituted to serve constituents within their jurisdictional boundaries, shoved-out communities are unincorporated and, therefore, lack the autonomous legal and political right to levee fees (i.e., taxes) to expand and sustain service provision or to participate fully in political processes. In the U.S., this form of environmental racism is furthered by state and

federal agencies, which reinforce disparities by restricting funds to incorporated communities [57]. The legacy of these legal—and political—constitutions reinforces existing racial hierarchies and disparate forms of citizenship [10,58].

Opt-out dynamics occur when communities leverage political or economic power to refuse centralized water or divert shared water resources. This may happen, for example, when powerful communities decline municipal water service extension, promote political or economic divestiture from public water infrastructure, and/or simultaneously engage in individual or communal water projects. Practices such as water grabbing where farmers divert a disproportionate volume of water to their farms at the expense of other water users perpetuates water inequities. Often, though, the consequences are rationalized. To the farmers, their water privileges are sensible and fully in accordance with liberal thinking: water should be given to those best able to realize profit from it. Alternate water use systems outside these economically rational forms are derided as inefficient. Privatization is another key, and related, example. Privatization is touted as the most economically efficient system, yet evidence demonstrates that public-private partnerships (PPPs) benefit the private actors more than public ones [59]. In the U.S. South, white communities have historically developed through the extraction of resources, including water and human labor, from Black and Indigenous communities, creating inequities and reifying white spaces as deserving and desirable [60,61]. Opting out reflects the ability of more powerful communities to manifest privilege to achieve their ends, and the challenge lies in the fact that these neoliberal political economic paradigms are dominant and considered just by proponents. By highlighting the multiplex and relational nature of “justice” from the outset, these exclusionary practices fundamentally complicate our understanding of water justice [59].

### 4. Injustices in MAD water systems

Recent convergent scholarship has proposed a framework for theorizing injustice in MAD water systems that centers on five forms of justice: distributive, procedural, interpersonal, recognition, and transformative/restorative [25]. Opt-out and shove-out dynamics are key to understanding water injustices in MAD water systems, yet their integration with MAD water justice frameworks remains theoretically nascent. Our paper begins by defining each form of justice, briefly reviewing the intellectual histories that connect it to water, and suggesting ways that these literatures might explain opt-out and shove-out dynamics.

#### 4.1. Distributive justice

Distributive justice, the most studied form of environmental justice, is concerned with the fairness of resource access and outcomes [62–66]. In MAD water research, distributive justice can be assessed based on water quantity, water pricing, and water quality [25]. Opt-out and shove-out dynamics may create disparities in water quantity and quality between ethnic-majority and ethnic-minority communities and between high-income and low-income households.

#### 4.2. Procedural justice

Well-documented in the environmental justice literature, procedural justice concerns whether the rules for environmental management are fair and equitable [62–66]. In MAD water research, procedural justice can be assessed through fairness in processes, transparency, participation, and decision-making [25]. Opt-out and shove-out dynamics may create disparities in who has access to decision-making (e.g., racialized political exclusion), denial of services to improve water delivery (e.g., redlining or failures in water quality monitoring), and exclusion from collective governance of water (e.g., municipal underbounding).

<sup>1</sup> Similar dynamics have been described in other contexts as “push back/forward” or “pull back/forward” (e.g., [53]).

### 4.3. Interpersonal justice

While infrequently studied to date, there is some evidence that interpersonal injustices are among the most distressing forms of environmental injustices [67]. It concerns whether people are treated in a fair and equitable way. In MAD water research, interpersonal justice can be assessed based on people's reports that they have personally been treated unfairly or discriminated against (e.g., based on gender, race/ethnicity, low income) [25]. Opt-out and shove-out dynamics may create interpersonal injustices, for example, when water vendors or municipal workers deny water service one-on-one (e.g., [68]).

### 4.4. Recognition justice

Recognition justice has been a core concern in environmental justice for at least the last decade [69,70]. It addresses the fair inclusion, recognition, and representation of diverse worldviews [69]. In MAD water research, recognition justice can be assessed based on whether values aligned with diverse cultures are included in water governance [25]. An example may include Anishinaabek reciprocal obligations to care for, and love water [71], which are core to their water governance principles. Opt-out and shove-out dynamics may create recognition injustices by blocking Indigenous communities from securing water sovereignty and self-determination (e.g., [72,73]).

### 4.5. Transformative/Restorative justice

Transformative (or restorative) justice is a recent, emerging focus of the environmental justice literature [10,74–76]. In MAD water research, restorative justice centers around truth and reconciliation, collaboratively addressing the root causes of injustice, and using reparations and other system-level approaches to remediate harms [25]. Méndez-Barrientos et al. [10] have recently argued that there can be no integrative move toward distributive, procedural, and recognition justice without core efforts to address transformative and restorative justice. Opt-out and shove-out dynamics may be one way of conceptualizing the inequitable and discriminatory dynamics that make transformative/restorative justice necessary in water systems.

With these justice dimensions defined, we now discuss how opt-out and shove-out dynamics shape injustices in MAD water systems. To the extent the literature allows, we examine how opt-out and shove-out MAD water systems produce these five kinds of injustices. We then present three case studies from the U.S. to illustrate how water injustices result from opt-out and shove-out dynamics in MAD water systems. We use this grounded case study approach, centered on U.S. cases, because justice is relationally constructed in ways that are place- and context-specific [62,77].

## 5. North Carolina: Shove-out and opt-out dynamics of MAD water

Shove-out and opt-out processes occur in North Carolina. The former occurs through selective municipal annexation or underbounding ([78]; cf. [55]), and disproportionately impacts Black communities [79,80]. As one of many examples, underbounded and predominantly Black neighborhoods around Mebane, North Carolina lack sufficient access to water and sewer and are simultaneously burdened with environmental disamenities, including a water treatment and recovery facility, hazardous waste sites, and a large industrial park area [81]. Residents of this region use hybrid MAD water systems, including a combination of unregulated private wells, public drinking water, sewer, and septic systems [81–83]. This demonstrates the core fundamentals of distributive and procedural injustices: Black communities in these contexts are burdened with environmental hazards and are unable to vote for local change [55,61,80]. Such exclusions increase residents' reliance on MAD water systems.

A corollary process, known as “defensive incorporation” [84], occurs where previously unincorporated areas incorporate and form small governments. Defensive incorporation is most common in majority white communities [85], and North Carolina is a national leader for the number of new towns created [86]. Workman and Shah [61] recently demonstrated how one such community leveraged political representation and then-existing state policy to “defensively incorporate” into a town. Preventing water and sewer connections became the rally cry against development—development that community members feared would fundamentally change the character and aesthetic of the Town [61]. While residents spoke of maintaining rurality, defensive incorporation was mobilized through systems of white privilege [87], effectively maintaining the community as a nearly entirely white and wealthy enclave [61]. The Town does not have a public water or sewer system, relying instead on individually owned wells and communal wells that are owned and/or operated by private entities ([61]; see [88]). This research, like others, demonstrates how shove-out and opt-out in North Carolina must be understood in the context of historical and ongoing racial segregation (e.g., [61,80,81,89]).

Water infrastructure is an important defining feature of boundary-making. Processes such as defensive incorporation can be not only used to exclude but also to protect. In the U.S., there are examples of some communities of color incorporating [80,89,90], but evidence suggests communities of color continue to receive disproportionate environmental disamenities regardless of incorporation status [80,89,91]. Communities of color can potentially facilitate a form of recognition justice or restorative justice through activism aimed at municipal policy, but the continued inequities highlight the need to contextualize incorporation and infrastructural (dis)amenities in larger systems of racial and other injustices. MAD water systems may be preferable to municipal systems ([90]; cf. [89]) and serve as a potential step toward improved infrastructural equity if sufficiently attuned toward the larger drivers of exclusion and environmental injustices. For more powerful, white-majority communities, opting-out can minimize financial contributions to existing systems, effectively creating inaccessible tax caches in defensively incorporated towns. The motivations for and repercussions of opting-out, then, are contingent on relative power and underscore the similarly relative nature of justice.

## 6. Distributive injustices: A shove-out case of MAD water in Texas colonias

Water is a contentious issue in the Rio Grande Valley of Texas, a four-county region at the southern tip of Texas U.S.-Mexico border. For informal settlements on the peri-urban/peri-rural periphery of the U.S.-Mexico border towns, known as *colonias*, flood vulnerability and non-potable drinking sources are two manifestations of distributive injustice.

Historically shoved-out colonias were excluded from a centralized water system. Colonias formed in the mid-20th century due to population pressures and rapidly increasing housing demand and were largely developed without state oversight through informal, clandestine, and incremental practices [92]. These largely Mexican/Mexican American communities are often situated in flood-prone, unincorporated areas on the urban fringe [93]. Due to the unincorporated nature of colonias and their peri-rurality, “underbounding” [55]—the exclusion of colonias by city governments from centralized water lines as they fall outside of utility service areas—is a chief mechanism by which colonias are excluded from centralized water systems [14]. Given this limited access, many households rely on septic tanks for sewage and wells/private companies to deliver water [94,95].

Colonias also experience heightened flood exposure due to inadequate drainage and inconsistent, out-of-date floodplain data [96,97]. These decentralized water systems, in combination with persistent flood exposure, increase water insecurity as colonia residents are regularly unable to drink their water for days, or even weeks, after a major flood event due to flooded septic tanks that contaminate decentralized water

supplies [94,96]. In addition, as many colonia roads are unpaved, households are often trapped until the water abates, which can take days or weeks [96]. This flood exposure intensifies vulnerability as many colonia residents are also shoved-out of post-flood federal support due to discriminatory federal policy [98,99].

This high degree of water precarity has given rise to MAD water systems: informal adaptation strategies that enable survival, such as water sharing networks, collaborative rebuilding, and creative ad hoc home modifications [14]. Water sharing is crucial to post-flood survival; the generosity of neighbors sharing water bottles is necessary as major flood events contaminate local water supplies and flooded roads are impassable [99]. Similarly, residents describe relying on kinship networks—such as family, in-laws, and neighbors—in the rebuilding process; stories of sharing construction material and building expertise are common [100]. These rebuilding efforts tie into ad hoc home modifications including elevating homes to avoid future flooding, plugging leaky roofs with on-hand materials, and drinking tea to alleviate asthma caused by mold—a rampant long-term side effect of flood exposure [99,101]. Beyond the Rio Grande Valley, scholars analyzing colonias in the El Paso region have documented informal water collection and retention systems to improve water access [102]. Unfortunately, while solidarity and creativity are powerful adaptive tools, these MAD water systems are ad hoc interventions that rarely manifest in stable access to potable water or post-flood recovery [99].

Distributive injustices, and the multifaceted vulnerability of shoved-out colonias, are the result of race-based discrimination operationalized through exclusion, violence, and structural inequality [98]. Shared values and norms have allowed households in the Rio Grande Valley to access water. Yet, their experiences of economic precarity and poor public health outcomes speak volumes; existing water access activities (i.e., water sharing and solidarity economies) are only a band-aid to the legacy of settler colonialism, racial violence, and inequitable policies that have dominated the region throughout its modern history [103].

## 7. Procedural (in)justices: Shove-out and opt-out cases of MAD water in California

Thousands of unincorporated communities in California live outside of municipal boundaries and centralized water systems [104]. Institutional fragmentation and decentralization are the norm [105,106]. Some of these communities have been shoved-out and others have purposely opted-out of these systems, with environmental racism implicated in both processes [80,87,89,91]. As we explain here, procedural injustices like political exclusion play a major role.

Shoved-out communities emerged alongside towns and cities and commercial farms, mostly as farm labor communities [107]. To date, municipal underbounding efforts continue to limit their incorporation into central water systems [10,104]. Consequently, shoved-out households continue to rely on self-supplied drinking water from shallow private groundwater-wells or small water systems with higher-than-average water quality violations [10,105]. In contrast, opt-out communities emerged at the peripheries of growing urban areas as white-only enclaves [108]. Unlike shoved-out communities who source water in diverse ways, opt-out communities commonly rely on nonprofit, small water systems, such as mutual water companies for drinking water provision [109].

Unincorporation has not only limited access to water, but it has also impacted access to water governance [10,11]. Shoved-out communities have been excluded from public agencies and have generally not formed their own water agencies due to a history of exclusion in water governance networks [12,110]. This has only recently and narrowly started to change with the appointment of water justice activists to central government roles [111] and the passing of the Sustainable Groundwater Management Act (SGMA), which expanded opportunities for participation in local groundwater governance processes [11,112]. Nevertheless, local state agencies have been mostly absent in assisting these

communities, who instead rely on the advocacy and support of central government actors and advocacy organizations [104].

An additional complicating factor is the role of everyday water management in shoved-out communities. Expressions of solidarity are affirmed through water sharing in times of drought [113,114], co-management of small water systems [115], and collective-action in water justice organizing [10,104]. These everyday water management acts may facilitate interpersonal justice among residents of shoved-out communities.

Opt-out communities have leveraged nonprofit governance structures to operate water systems. Like public agencies, nonprofit utilities are tax-exempt organizations, but unlike their government and private counterparts, nonprofits largely operate in a regulatory vacuum [108,109]. This governance structure facilitates many advantages internally to opt-out water systems. For instance, McBride [108] reported that some opt-out utilities operate as lifetime appointments for board members, rarely hold meetings with their members even though they are supposed to hold their own elections and are not subject to open meetings laws that apply to government agencies. This suggests procedural injustices exist in opt-out nonprofit utilities, reinforced by the lack of transparency, oversight, and interaction among members that this governance structure lends. Externally, however, this governance structure has generally facilitated access, representation, and decision-making—for these opt-out communities—in water governance processes. In short, the institutional set-up of opt-out water systems shapes social and governance interactions, creating complex configurations of procedural justice and injustice.

We observe that the assumption that "governance is neutral" is undermined through the exercise and experience of environmental racism in local water governance processes. Despite some indications that MAD water systems in shoved-out communities can promote interpersonal justice, these systems seem to be distinguished by a larger number of distributive and procedural injustices. These California communities experience higher water quality violations [105] and diminished resilience against droughts [36,116]. In other words, the decentralized nature of these systems, regardless of their institutional diversity, are characterized by a lack of transparency, solidarity, and right to water; this largely serves to reinforce and perpetuate procedural injustice.

## 8. Conclusions

Our goal here has been to identify how shove-out and opt-out dynamics create injustices in MAD water systems. Justice-oriented MAD solutions must be attuned to the role of social inequalities, and the different ways communities leverage existing social networks and resources, to situate MAD solutions in the broader historical context. Such work, we argue, can ultimately enable more just and equitable MAD interventions. In this paper, we focused on three case studies from the U.S. that exemplify some key patterns of inequity in MAD water systems. We have illustrated ways in which MAD water systems pose significant challenges—particularly when shove-out systems are paradoxically the result of procedural injustices and produce profound distributive injustices *but also* open pathways to interpersonal, recognition, and transformative/restorative justice for marginalized Black and Hispanic communities. Considering distributive and procedural justice are well-documented in the literature, future research is needed to analyze shove-out and opt-out dynamics using the lenses of interpersonal, recognition, and transformative justice to provide new understandings for research, policy, and interventions.

In the U.S. specifically, dynamics of racial and economic inequality produce challenges through which communities require MAD solutions [117–130]. A grounded approach—that closely examines racial dynamics of exclusion in centralized water systems—is valuable because experiences of water injustice and notions of water justice are localized and may not be uniformly or universally shared [10,62,77]. Our study

may have limited generalizability beyond the U.S.; there is long history of scholarship establishing that people in the Global South suffer disproportionately from water injustices [8,131–135]. Recent scholarship suggests that similar dynamics of inequality, under-investment, and systemic racism underscore water injustices in the Global North and Global South alike [5,10,19,73,104,136–140]. Future research is needed to conceptualize MAD water injustices—and the opt-out and shove-out dynamics that underlie them—in ways that span the Global North and Global South.

MAD water systems are not inherently just or unjust. As the U.S. cases we reviewed demonstrate, such systems have served as a response to historical legacies and developed through formal and informal systems as expressed through policy, law, and norms. Yet more research is needed to understand these patterns at a broad global level. Future research could leverage existing global case data to analyze and assess justices and injustices in MAD water systems, ideally using systematic methods like meta-analysis and Qualitative Comparative Analysis [141]. Building from the more complete definitions and descriptions we provide here, such research could test (1) modular, adaptive, and decentralized approaches to (2) harvesting, treating, distributing, monitoring and/or governing water or wastewater to determine if these are associated with (3) opt-out or shove-out dynamics that (4) produce distributive, interpersonal, procedural, recognition, and transformative/restorative justice.

Our review, albeit partial and exploratory, suggests that technological advances associated with MAD water systems could reproduce *longue durée* systems of inequality. As such, future research on MAD water should consider other social-political-economic and historical dynamics of diverse global communities, including social structural problems such as coloniality, capitalism, ethnicity, and gender in creating water injustices. Viewing water as a human right and a biological need for all life, we echo Stoler et al. [24]s caution that systemic inequalities and injustices must be part of any analysis deploying new MAD water systems.

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## 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.

## Data availability

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

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