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PERSPECTIVE

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Delivering global water security: Embedding water justice as a response to increased irrigation efficiency

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Abstract

Increasingly, irrigation infrastructure upgrades have been regarded in global policy as a solution for both water scarcity and low agricultural productivity. However, these technical "fixes" may ultimately prove to be dangerous shortcuts that do little to address the concerns of irrigators, Indigenous People, environmental groups, and local communities about water scarcity, access, security, and sustainability. In the absence of transparent and rigorous governance safeguards, irrigation efficiency upgrades can result in higher water consumption, demand, and ultimately, increased water scarcity. Upgraded irrigation systems also tend to capture return flows and redistribute them to "high value" consumptive water uses, potentially displacing other users and uses, including Indigenous Peoples. In this article, we critique current approaches to governing irrigation efficiency, using a water justice lens to identify four key insights and their implications for governance. We propose new governance pathways and options that take into consideration hydrological realities and the full range of water demands and needs.

This article is categorized under:
Human Water > Water Governance
Water and Life > Conservation, Management, and Awareness
Human Water > Water as Imagined and Represented

KEYWORDS
climate change adaptation, governance, Indigenous Peoples, irrigation efficiency, water justice

1 | INTRODUCTION

There exists a paradox in many irrigation areas around the world, known as the "rebound effect," where infrastructure upgrades designed to "save water" by improving irrigation efficiencies, such as converting to piped delivery or pressurized drip irrigation systems, often lead to increased water consumption and demand (Grafton et al., 2018; Perry & Steduto, 2017). When water consumption caps are not imposed, monitored, and effectively enforced, irrigators can use "wasted" water to grow more water-consumptive crops, expand irrigation areas, or otherwise intensify production (Grafton et al., 2018). The increase in consumption may result in a reduction in recoverable return flows, namely the amount of irrigation water that seeps into groundwater, flows into rivers, and is often captured and used for other purposes, such as environmental sustainability and by Indigenous Peoples for cultural and economic purposes (Adamson & Loch, 2014; Grafton et al., 2018). In this way, increasing water efficiency may unintentionally increase water consumption, demand, and ultimately, water scarcity elsewhere (Wheeler et al., 2020).

Widespread irrigation upgrades, for instance, have contributed to groundwater decline in Kansas, USA as increased efficiency allowed farmers to divert and consume more water per hectare on irrigated fields or irrigate a larger portion of their fields. Farmers were also less likely to plant dryland crops or leave fields fallow, increasing water demand (Pfeiffer & Lin, 2014; Zwickle et al., 2021). Savings from irrigation efficiency improvements in the Guadiana Basin between Spain and Portugal were repurposed to expand irrigated areas, increase yields, and diversify production, which increased overall consumption (Scott et al., 2014). At the same time, water shortages for some users and uses have increased, as improved irrigation efficiency hydrologically reduces return flows to rivers and reallocates that water to so-called "higher value" uses such as export crops (Perry, 2007; Wang et al., 2018). There are estimates that irrigation upgrades in the Murray–Darling Basin (MDB) in Australia have reduced both recoverable return flows and instream flows, and that these impacts have not been considered sufficiently by governments implementing the 2012 Murray–Darling Basin Plan (Williams & Grafton, 2019).

Yet, irrigation efficiency remains a key mantra in global water policy and is frequently justified by the need for food security (see, e.g., D'Odorico et al., 2020). Over 70% of the world's water withdrawals come from irrigated agriculture, which accounts for 40% of global crop production and which will face greater competition for limited water supplies (Organisation for Economic Co-operation and Development and Food and Agriculture Organization of the United Nations, 2020; Perry & Steduto, 2017; United Nations, 2018). Convened specifically to accelerate the implementation of Sustainable Development Goal 6 (SDG 6), the World Bank's High-Level Panel on Water warns that portions of agriculture water allocations "can be lost through evaporation and non-productive seepage" and focuses on measures to reduce these "losses" through on-farm and off-farm measures "while not eroding beneficial return flows" (High-Level Panel on Water, 2017, p. 7).

These infrastructure fixes may ultimately prove, however, to be dangerous shortcuts that do little to address water scarcity, security, and sustainability concerns of irrigators, Indigenous Peoples, environmental groups, and local communities. The causes of water scarcity and food insecurity are not physical or "politically neutral," but are often socio-economic and include the forces of globalizing agribusiness that increase marginal water productivity (Birkenholtz, 2017; Boelens et al., 2016; High-Level Panel of Experts, 2020; Lankford, 2012; Zwickle et al., 2021); the exchange between Ben Crow and Yoram Eckstein in Bellaubi and Bustamante (2014). In this context, improved irrigation efficiency reallocates water and privileges certain formalized water uses and users (i.e., irrigators and advisers and donors connected to irrigation; Lankford, 2012, see also Jackson, 2018; Scott et al., 2014), but is promoted as a key tool for addressing water scarcity and achieving various SDGs, including SDG 6 in water-stressed regions including

Northern Africa and Western, Central, and Southern Asia (Perez-Blanco & Perry, 2020; United Nations, 2018). Against this backdrop, irrigation efficiency upgrades have become a central issue in debates about governance to address SDGs, human rights, and climate change (Perez-Blanco & Perry, 2020).

2 | CRITIQUING GOVERNANCE AND OVERCOMING THE PARADOX OF IRRIGATION EFFICIENCY: FOUR ANALYTICAL INSIGHTS FROM WATER JUSTICE

Overdevelopment of irrigation systems, reallocation of water, and degradation of water resources and ecosystems are not just "scientific" or "technical" issues, but equally problems of "governance" (defined here as the processes of intervention under law and regulation[1]; Drahos & Krygier, 2017; Zhu et al., 2019). Governments, through governance frameworks, are enabling and relying on irrigation efficiency upgrades as a political tool to address complex questions of physical and economic water scarcity, competing demands, and adaptation to climate change (see, e.g., Perez-Blanco & Perry, 2020; Swyngedouw, 2015). However, overreliance on irrigation upgrades as an adaptation strategy is a reductionist approach that can increase water demand and consumption, and overlook multiple competing values, needs, demands, and perspectives on water.

This article does not aim to dissect the paradox of irrigation efficiency, but rather to examine the social and economic implications of the efficiency paradox and the governance measures needed to overcome the dominant paradigm. We are not the first to identify that irrigation efficiency upgrades pose problems for water conservation, or that governance reforms are required (see, e.g., Dagnino & Ward, 2012; Hanak, 2011; Lankford et al., 2020; Perez-Blanco & Perry, 2020; Ward & Pulido-Velazquez, 2008). Studies have focused on structural reforms through water caps, water pricing, and market implementation, as well as the need to improve water measurement and accounting (Howitt & Hanak, 2005; Toan, 2016; Zwickle et al., 2021). We extend this work by placing our analytical focus squarely on questions of water justice. The goal is to identify pathways and opportunities for better governing irrigation efficiency to overcome or flip the efficiency paradox. In doing so, we push away and forward from predominant water discourses for managing water to a more inclusive governance model that empowers the full range of water users and reflects hydrological truths (Grafton et al., 2019; Lempert & Kalra, 2011). Our approach to water justice encompasses equitable water distribution, political and cultural recognition (e.g., of cultural identities, rights, and practices); participation (in water management decisions; Schlosberg, 2004; Zwarteveen & Boelens, 2014); and the need to sustain the riverine environment and guarantee the livelihoods of current and future generations (Zwarteveen & Boelens, 2014). In so doing, we integrate hydrogeological insights with the social, technical, cultural, and legal factors that determine the specific impacts of irrigation efficiency. Four key analytical insights emerge from a water justice lens, which has particular implications for governance.

First, water justice examines how hydrological complexity can obscure water reallocation and its effects on people and the environment at various scales. Enhancing resilience through irrigation upgrades that conserve water at the field level, for example, can reduce recoverable return flows and rainfall at the catchment or basin level. This reduction can affect not only the environment but also access to water by marginalized groups or individuals who were not included in water allocation frameworks (Allen et al., 2017a). There are also links between local levels of dispossession and appropriation and the growth of global agribusiness, which has contributed to industry rationalization and the aggregation of farming holdings (Rosewarne, 2019). Water's fugacious nature, therefore, requires an appreciation of how decision-making outcomes differ across a multitude of scales, from the farm to the basin, upstream, and downstream (Zwarteveen & Boelens, 2014).

Second, water justice highlights the importance of water governance frameworks that adopt agreed-upon definitions and reflect hydrological realities. The terms "water withdrawal," "water use," and "water consumption" are often used interchangeably in water governance, and a failure to distinguish between them can lead to governance failures. Water withdrawals (or diversions) refer to how much liquid water is withdrawn from a surface or groundwater resource, whereas water consumption refers to how much liquid water is transformed into water vapor by plants, microbes, animals, and people through evapotranspiration (ET; Wada et al., 2016). In governance systems based on water withdrawals, farmers are entitled to take a certain amount of water, and "savings" that result from increased irrigation efficiency do not normally affect that right. Upgrades to infrastructure that increase efficiency can therefore enable the water recovered to be reused locally and actually increase private water consumption, reduce public benefits (especially for downstream users such as local communities relying on subsistence agriculture and Indigenous Peoples), and

increase water scarcity (Grafton et al., 2018; Williams & Grafton, 2019; Zhu et al., 2019). Irrigation efficiency is more likely to conserve water when governments define and set total limits on consumption, as well as withdrawals, which are specified in water laws and inter-state compacts. Within those caps, water justice requires both environmentally sustainable and equitable distributions of water (Hoekstra, 2014).

Third, water justice explains how different actors shape, control, and influence water governance (Boelens et al., 2018; Hartwig et al., 2022; Zwarteveen & Boelens, 2014). Settler-colonial histories have influenced water regulation and management regimes around the world, for example, as settler-states appropriated and developed water resources to "nation build" (Hartwig et al., 2022). The water regulation emerging from this period is often responsible for water injustice, as it marginalizes Indigenous People, restricts their access to water resources, and impedes their ability to accumulate capital (Hartwig et al., 2022; Jackson, 2018). Berry and Jackson (2018, p. 1358), when referring to Australia and the US, explain how the development of irrigation agriculture was accompanied by "racially advantageous" and "exclusive" property rights regimes that included water allocation systems and publicly funded water infrastructure. Maintaining the stability of these regulatory systems often means overlooking or negating the ongoing impacts of these settler-colonial structures by applying one rule "for the benefit of all" (Boelens, 2009, pp. 309–310), and irrigation efficiency, as an extension of these structures, has the potential to amplify these inequities and is "prone to capture" by actors that engage with irrigation and their "donors, advisers, and irrigation engineers" (Lankford, 2012, p. 37). Water justice draws focus to these path dependencies and their impacts on the range of water rights and interests.

Fourth, and relatedly, water justice decodes the discourses that are used to articulate water management and allocation. We use the concept of water justice to critique the concepts of "efficiency" and "waste" and to prevent the erasure of certain community, environmental and indigenous voices, and interests from decision-making in relation to important water management decisions (Allen et al., 2017b; Zwarteveen & Boelens, 2014). Policies designed to maximize "efficiency" and production within certain market-based consumptive uses can encode a particular understanding of a "high value" use within a water system (such as for export crops) while failing to acknowledge other legitimate uses and users of return flows. Capturing and *reallocating* water to crops having a high market value then reduces water that historically provided return flows to other water users and uses (Hartwig et al., 2020; Horne et al., 2018; Jackson, 2018). In water justice, the impact of "supposedly neutral efficiency terms" is explored as well as means of legitimizing reallocation of water to "ranked" users and uses (Boelens & Vos, 2012). These management paradigms can result in structural scarcity of water, causing unequal participation and access to water.

3 | EMBEDDING WATER JUSTICE IN GOVERNANCE

Water injustices often occur in conditions of hydrological complexity and uncertainty. To reduce the potential for this complexity to be exploited, irrigation efficiency upgrade programs, and projects should only be implemented where water consumption is directly regulated. To this end, governments must define and set total limits on *consumption*, as well as withdrawals, which are specified in water laws and inter-state compacts, and commit to environmentally sustainable and equitable distributions within those caps (Hoekstra, 2014; Perry, 2007). In regulating consumption, governments will need to focus on managing evapotranspiration (ET) at a range of scales, particularly in arid and semi-arid basins where ET from irrigated agriculture comprises a significant portion of water consumption (Wu et al., 2014). Satellite sensor technologies and remote sensing applications that can support estimation and monitoring of regional or catchment scale water use, such as ET from thermal infrared imagery and flooding, are quickly becoming a vital support for regulators (Allen et al., 2005; Wu et al., 2014). The spatial resolution of optical sensors has now increased to provide images at the meter or sub-meter level (Huang et al., 2018).

In the arid and remote Turpan Basin in northern China, for example, water supposedly "saved" through irrigation efficiency upgrades had been previously diverted to expand irrigated areas, resulting in over-consumption of groundwater systems and degradation of ancient karez water systems (World Bank, 2019). To reverse these trends, the Xinjiang Turpan Water Conservation Project (the Project) began to utilize ET-based methods to achieve real savings by reducing consumptive use, and specifically nonbeneficial ET (Doczi et al., 2014; World Bank, 2017). Supported by advanced remote sensing and geographic information system technologies, and drawing on existing laws and institutions (World Bank, 2013, 2019), regulators are able to measure ET from agricultural areas within the area, and use that data to cap water withdrawal, establish a water consumption balance, and then allocate water to different uses, including for irrigation, based on a sustainable water balance (World Bank, 2013, 2017). The project is achieving demonstrable results,

with a combination of ET-based caps on consumption and irrigation and agronomic interventions reducing the actual ET in its irrigation areas by over 17 million cubic meters (World Bank, 2017). Certain enabling conditions will be required, however, before an ET-based system can be adopted by other jurisdictions and regions. Experience with remote sensing and GIS systems for forest carbon projects also indicates that top-down technological insights should be combined with local participation to interpret and use that data, and processes for hearing, responding to, and resolving community and stakeholder grievances (Eilola et al., 2021; Suiseeya & Caplow, 2013).

Reallocating water through irrigation infrastructure upgrades, and relying on discourses of efficiency to justify decisions, can also obscure complex distributional injustices and trade-offs between irrigation, cultural, environmental, and agricultural production needs. Identifying who benefits and who loses from decisions is a crucial first step in unmasking water injustice (Diep, 2018). Yet, despite the clear potential for adverse distributional impacts, governance frameworks do not currently include comprehensive regulatory assessment criteria to render these trade-offs more visible or to generate information, reveal unintended consequences, and ensure the additionally of a particular upgrading project.[2] Proponents and program administrators should be required to answer fundamental questions such as Whose demands are being considered? Where is that water currently flowing? What is the definition of "wasted" water? Which users are excluded from the water allocation system? What are the third-party impacts of an irrigation infrastructure upgrade? What are the cumulative impacts of irrigation projects across the basin or catchment (i.e. beyond the project)? Further questions include who pays for water and who bears the capital and maintenance costs of new infrastructure, given the colossal expense when irrigation infrastructure is publicly subsidized (Grafton & Wheeler, 2018; Wittwer & Dixon, 2013). Under these assessments, irrigation upgrades are more likely to be deployed to conserve water in those areas that have less use for or nonrecoverable return flows or demands for informal or customary uses. The assessment framework should be bolstered by rigorous cost–benefit and hydrological analyses that examine the net social and ecological benefits and costs of any proposal (including outcomes for Indigenous Peoples) and the impact of greater extremes and uncertainties due to climate change.

Equally important to regulatory assessment is the need to develop new inclusionary mechanisms for those uses and users that have been excluded from water allocation regimes. Irrigation infrastructure upgrades are being implemented in locations where Indigenous water rights may never have been ceded, or where customary uses may never have been abolished, but such rights are not formally recognized (Godden et al., 2020). The hegemony of the efficiency paradox will not change unless governance frameworks enable all affected interests, including Indigenous People, to participate and deliberate well in decision-making. To do so, participants will need transparent and accessible information that opens the "black box" of irrigation efficiency and its potential impacts. Broad and meaningful participation will not

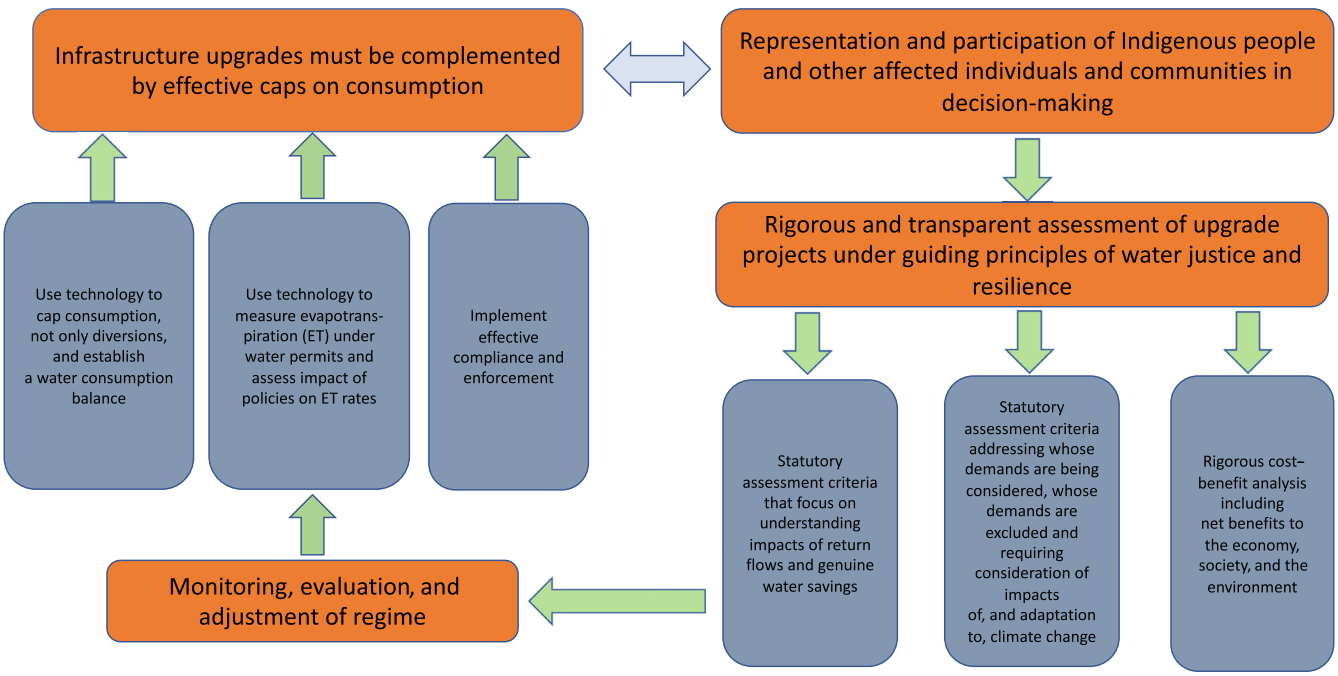

FIGURE 1 Embedding water justice in irrigation efficiency governance

only improve the legitimacy of water governance regimes but also highlight the risks and responsibilities that attach to projects and enable project implementation on a more sustainable basis within socio-economic systems (Zwarteveen & Boelens, 2014).

Ultimately, it will be up to regulatory decision-makers to make more transparent decisions about which water users and demands are likely to bear the costs and losses associated with irrigation infrastructure upgrades and associated changes in water consumption. In making decisions on programs and projects, regulators should be able to identify relevant water system states (including dependent environments and ecosystem services), drivers of change, potentially affected individuals, and communities at various scales and how those people and communities are going to be included and represented in decision-making. Public money spent on irrigation infrastructure upgrades must be strongly justified as having a net economic benefit overall. Regulatory decisions should be based on the best available science, including traditional knowledge, accounting for key systemic risks, and supporting self-determination. Publicly available remote-sensing-based hydrological, ecological, economic, cultural, and social system performance metrics should be used to monitor, review, and adjust projects and programs (Grafton et al., 2019). Additionally, public money spent on irrigation infrastructure upgrades must be clearly justified as having a net economic benefit (Figure 1).

4 | CONCLUSION

Irrigation efficiency has been a mantra of global and national water policy leaders but, without effective management of liquid water consumption and rigorous assessment and evaluation, these measures are being implemented without safeguards or accountability for future governance and equity failures that are inevitable. Yet, although irrigation efficiency upgrading has exposed the key weaknesses we have identified in connection with water governance, it has also revealed the interventions that will be needed to create more inclusive governance models that can respond to the challenges posed by climate change. The impacts of irrigation upgrades can be much more transparent when governments set total limitations on liquid water consumption, as well as withdrawals, which are specified in water laws and interstate compacts and supported by satellite and thermal imaging technology. Governance tools must also elicit more rigorous forms of quantitative and qualitative data that offer decision-makers a deeper understanding of diverse perspectives and knowledge systems before public money is invested. Water justice requires that decisions reflect the social–ecological system in which the decision is made, and demonstrate a clear understanding of the vulnerabilities and power imbalances within a water allocation system and the expected net benefits of projects over time and space.

AUTHOR CONTRIBUTIONS

Katherine Owens: Conceptualization (lead); data curation (lead); formal analysis (lead); investigation (equal); methodology (lead); project administration (lead); visualization (lead); writing – original draft (lead); writing – review and editing (lead). **Emma Carmody:** Conceptualization (equal); data curation (supporting); formal analysis (equal); investigation (supporting); project administration (equal); writing – original draft (equal); writing – review and editing (supporting). **Quentin Grafton:** Conceptualization (equal); data curation (equal); formal analysis (equal); investigation (equal); methodology (equal); writing – original draft (equal); writing – review and editing (equal). **Erin O'Donnell:** Conceptualization (equal); formal analysis (equal); investigation (supporting); methodology (equal); visualization (supporting); writing – original draft (supporting); writing – review and editing (equal). **Sarah Wheeler:** Conceptualization (equal); formal analysis (equal); investigation (equal); writing – original draft (supporting); writing – review and editing (equal). **Lee Godden:** Conceptualization (equal); formal analysis (equal); writing – review and editing (equal). **Richard Allen:** Conceptualization (equal); formal analysis (equal); investigation (equal); writing – review and editing (equal). **Rosemary Lyster:** Conceptualization (equal); formal analysis (supporting); methodology (supporting); project administration (equal); writing – review and editing (supporting). **Pasquale Steduto:** Conceptualization (equal); writing – review and editing (equal). **Qiang Jiang:** Conceptualization (supporting); data curation (equal); formal analysis (supporting); investigation (equal); writing – review and editing (supporting). **Richard Kingsford:** Conceptualization (supporting); formal analysis (supporting); writing – review and editing (supporting). **John Quiggin:** Conceptualization (supporting); formal analysis (supporting); writing – review and editing (supporting).

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The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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ENDNOTES

[1] This definition allows us to examine the governance processes that produce the rebound effect across different contexts and scales (Drahos & Krygier, 2017).

[2] Namely, that sufficient amounts of previously unconsumed water are made available for reallocation above the original consumed volume, and the project allows for the reallocation of this unconsumed water at a basin scale.

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