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A plural knowledges model to support sustainable management of dryland rivers in western India

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Abstract

Direct and indirect human disturbances present major challenges to sustainable management of dryland rivers, impacting upon their role as critical lifelines in arid and semiarid regions. This paper presents an overview of changing human–river relations, knowledges and practices in the management of dryland rivers in western India over the last 4500 years. In ancient times, traditional knowledges underpinned local water harvesting techniques that worked with nature. Subsequent imposition of external values and knowledge frameworks in colonial times applied a command-and-control ethos that asserted human authority over rivers. Postindependence, development programmes in the second half of the 21st century further accentuated this legacy, with profound implications for river health. Discipline-bound approaches to river restoration in recent decades have failed to address these concerns. Using the Sabarmati catchment (∼20,000 km^2) as a case study, we develop a holistic, transdisciplinary approach that integrates traditional place-based knowledges and practices alongside scientific understandings and the generative potential of Big Data to show how a plural knowledges model can support proactive and precautionary approaches to sustainable river management.

KEYWORDS

adaptive management, geomorphology, nature-based solutions, socio-cultural relations, socio-natures

1 | INTRODUCTION

> The flow of water, in its material, symbolic, political, and discursive constructions, embodies and expresses exactly how the "production of nature" is both arena for and outcome of the tumultuous reordering of socionature in everchanging and intricate manners. … (M)odernity is deeply and inevitably a geographical project in which the intertwined transformations of nature and society are both medium and expression of shifting power positions that become materialized in the production of new water flows and the construction of new waterscapes.
>
> Erik Swyngedouw, 1999, pp. 449, 460

The quest for sustainability requires a fundamental shift in the way knowledge is developed and used to tackle root causes of the crises of our times, such as climate change and biodiversity loss, and their interconnected economic, socio-cultural, demographic, political, institutional and technological drivers (Albert et al., 2021; Bradshaw et al., 2021; Díaz et al., 2019). Unhealthy rivers and unsustainable management practices highlight the urgent and growing need to redress the imbalance between growth, development and river rehabilitation (Brierley & Fryirs, 2008; García et al., 2021). The United Nations Decade of Ecosystem Restoration (2021–2030) and the United Nations Sustainable Development Goals set out explicit targets for 2030 to deliver socially and environmentally just approaches to integrated water resources management through community inclusion and participation in freshwater ecosystem (river) management across Planet Earth (Ge et al., 2018; Russell et al., 2023; UNEP, 2020). As the IAHS Scientific Decade (2013–2022) entitled Panta Rhei (everything flows) draws to a close (Montanari et al., 2013), it is timely to reflect upon lessons from history, showing how path dependencies set by past/present management policies and practices shape prospects for more equitable, just and sustainable futures.

Socio-cultural relations to rivers have played a key role in the history of human civilisation (Macklin & Lewin, 2015). River flows connect people, places and other forms of life, inspiring and sustaining diverse cultural beliefs, values and ways of living (Anderson et al., 2019; Zingraff-Hamed et al., 2021). As key sites of conviviality and struggle (Boelens et al., 2023, p. 2) and as agents of social connectivity, rivers facilitate (or hinder) the communication and movement of people, goods, ideas and culture (Kondolf & Pinto, 2017). Water availability and river flows are intimately connected to human well-being, spiritual needs, cultural identity and sense of place. Water and society coevolve, making and remaking each other over space and time (Linton & Budds, 2014). River health provides a barometer of these coevolutionary, mutually interdependent and reciprocal relationships: healthy rivers are products of healthy societies and vice versa (Parker & Oates, 2016).

Inherently political processes shape material realities of waterways, and the legacy effects that ensue (Bouleau, 2014), as perpetually changing social and natural agents intertwine in the 'production of nature' (Smith, 1996; Swyngedouw, 1999). Historical, geographical and political processes shape the social construction and production of water, the ways by which it is made known, and the power relations that are embedded in hydrosocial change at a given place and time (Linton & Budds, 2014; Yates et al., 2017). Wantzen et al. (2016) outline how an eco-social approach works with nature and 'learns from the river', living with the rhythm of the waters, adapting management options in accordance with hydrological dynamics rather than fighting against them (cf. Wesselink et al., 2017). 'While "Nature" (as a historical product) provides the foundation, social relations produce nature's and society's history' (Swyngedouw, 1999, p. 446). Here we explore prospects to revive and reintegrate locally derived traditional knowledges that apply nature-based principles and practices to support sustainable management of dryland rivers in western India.

Dryland rivers flow in whole or in part through arid/semiarid regions (i.e., annual precipitation < 500 mm; Nanson et al., 2002). Pronounced spatial and temporal variability in flow creates 'boom and bust' rivers that are characterised by pulsed sediment and nutrient movement (Bunn et al., 2006). As dryland rivers offer the most accessible source of water in an otherwise arid environment, they are often subject to significant anthropogenic impact. Dams, water diversion schemes and excessive groundwater withdrawal reduce baseflow and increase the frequency of low flow (or no flow) events, impacting the biogeochemical functioning and ecological health of dryland rivers (Reid et al., 2016; Thoms & Sheldon, 2000). Urgent calls for carefully targeted, place-based management restoration programmes resonate loud and clear in moves to protect water-stressed systems that provide critical lifelines and crucial ecosystem services in the face of anthropogenic demands and climate change (Acuña et al., 2014; Larkin et al., 2020; Swarnkar et al., 2021).

Challenges of environmental and social sustainability in arid/semiarid areas are pronounced in countries such as India. About 45% of India's landmass has an arid to semiarid climate, supporting nearly 35% of its population and livestock (Mann, 1974). However, although rivers are celebrated and revered in Indian life, and countless festivals mark a long history of socio-cultural relations to rivers (Gottlieb, 2003; O'Keeffe et al., 2012), the appalling health of many rivers is a source of considerable socio-political alarm (Colopy, 2012; CPCB Annual Reports, 2020; Sengupta & Pandey, 2021).

For millennia, traditional knowledges underpinned locally adapted irrigation systems in India that incorporated water harvesting and storage techniques, hydraulic structures and wastewater facilities (Singh et al., 2020). Subsequently, British colonial assertions of a Rivered Eden imposed human authority over river systems through command-and-control engineering measures that conceptualised rivers as stable and predictable entities in the service of human society (Beattie & Morgan, 2017). Impacts of such framings were accentuated further in the period following independence when dams came to be viewed as the 'temples' of modern India (a phrase popularised by Jawaharlal Nehru, India's first prime minister; Upadhyaya, 2018) in programmes to support the socio-economic development of village economies at a time of intensive industrialisation and urbanisation. Significant deterioration in river health, in turn, eroded socio-cultural well-being and relations to rivers (Agarwal & Narain, 1997; Chakravarty et al., 2006; Dempsey et al., 2017). However, prevailing management regimes fail to engender sustainable outcomes, as fragmented discipline-bound understandings and incoherent institutional responses hamper approaches to river recovery and rehabilitation.

Here we show how nature-based solutions and systems thinking offer prospect to reinvigorate socio-cultural relations and enhance environmental conditions of dryland rivers in western India. To achieve this, following a brief summary of the regional setting we *firstly* review historical changes to human–river relations and water management practices in western India, reflecting upon the knowledge base that underpinned management actions. *Secondly*, we present a plural knowledges approach that frames place-based insights derived from contemporary science alongside traditional knowledges that underpinned local approaches to management of dryland rivers in this region. *Thirdly*, we use a case study of Sabarmati catchment to demonstrate how this plural knowledges lens can improve sustainable management practices for dryland rivers in India.

2 | REGIONAL SETTING: DRYLAND RIVERS OF WESTERN INDIA

Monsoonal rains and various other factors induce profound hydrological variability across the Indian subcontinent (Figure 1). Approximately

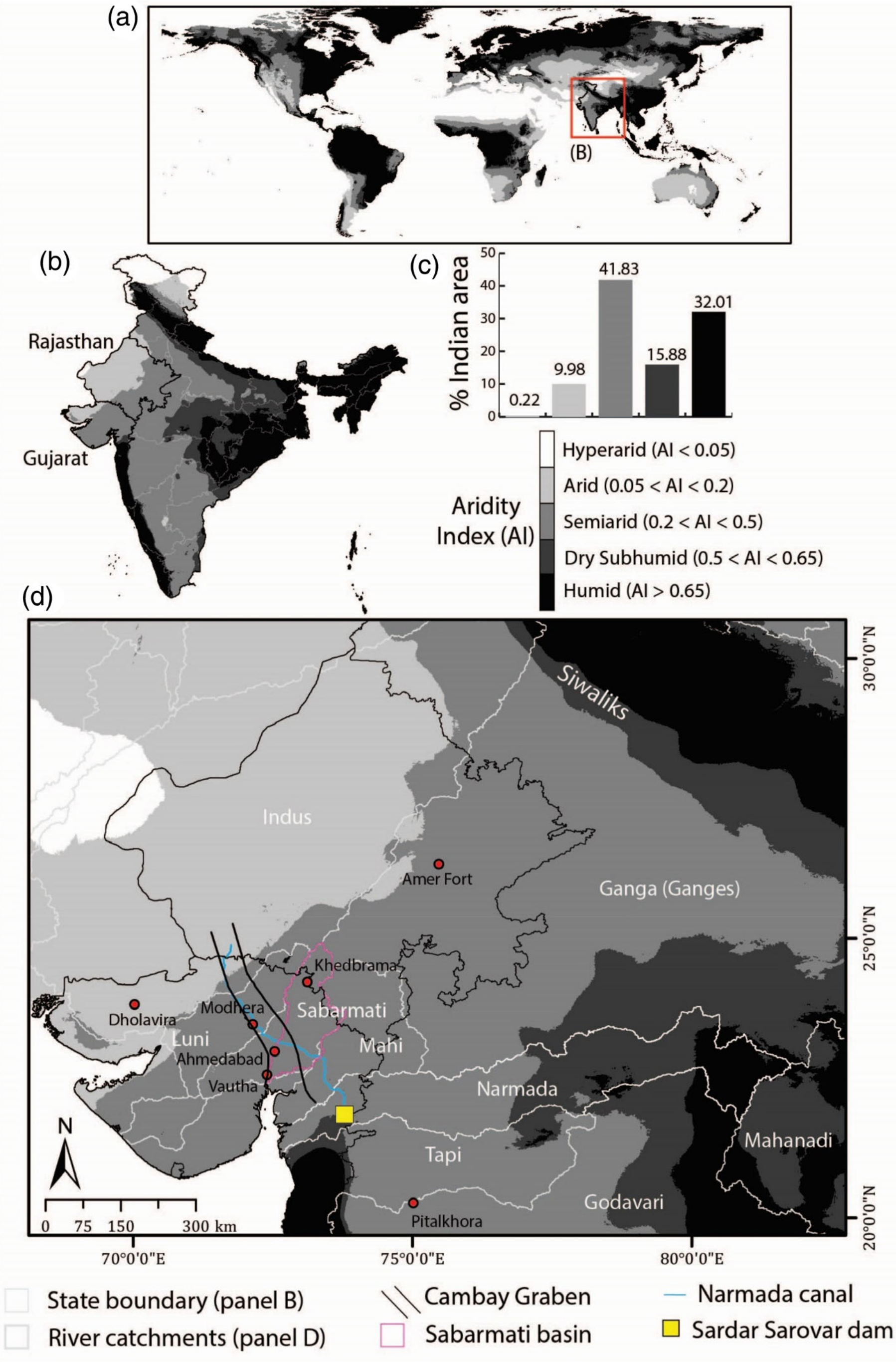
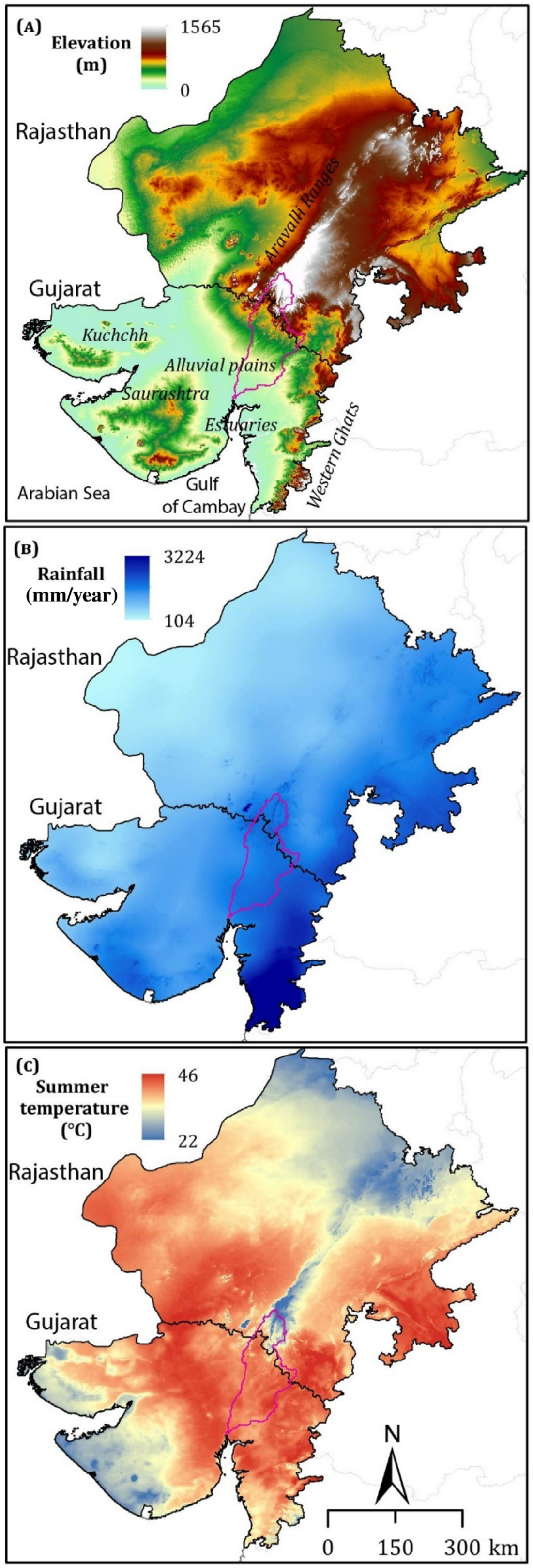


FIGURE 1 Aridity in India. (a) Global Aridity Index (function of precipitation, temperature and reference evapotranspiration; from Zomer et al., 2022), (b) India—note that the states of Rajasthan and Gujarat are dominated by arid and semiarid climate (Aridity Index < 0.5), (c) percentage breakdown of aridity classes across India (Aridity Index), (d) Aridity Index across north-western India. White boundaries outline major river catchments. Key locations are indicated in red. Data derived from Global Aridity Index and Potential Evapotranspiration (ET0) Database: Version 3—https://www.nature.com/articles/s41597-022-01493-1. [Color figure can be viewed at wileyonlinelibrary.com]

10% of the landmass falls in the arid category (aridity index between 0.05 and 0.2) and 41% in the semiarid category (aridity index between 0.2 and 0.5). Alongside regional climates, geological and physiographic settings induce significant geomorphic heterogeneity in dryland river systems (Tandon & Sinha, 2007). The terrain of north-west India comprises six major physiographic domains: hinterlands, alluvial plains, estuaries, the Western Ghats, Kuchchh and Saurashtra region (Figure 2a). Steep rugged terrain of the Aravalli Ranges serves as the hinterland for west flowing rivers such as the Luni, Sabarmati and Mahi rivers. After exiting the *hinterland*, rivers entrenched into vast Quaternary *alluvial plains* flow within the North–South aligned Cambay Graben before discharging into *estuaries* at the Gulf of Cambay in the Arabian Sea (Sonam et al., 2022; Srivastava et al., 2001).

Dryland terrains in western India are especially prominent in Rajasthan and Gujarat states, where annual average rainfall ranges from 104 to 3224 mm, respectively, while summer temperature ranges from 22 to 46°C (Figure 2b,c). The rainfall is higher in the coastal region, the Western Ghats and the Aravalli Ranges and progressively decreases inland. In recent decades, total annual rainfall has decreased at a rate of 0.5–2.4 mm/year (Jain & Kumar, 2012). Despite this, changing climate and anthropogenic forcing (especially water abstraction via canals, regulation via dams and responses to land use change and population growth) have intensified flood and drought events (Jain et al., 2017; Joshi & Makhasana, 2021; Shah & Mishra, 2016). The discharge of western rivers (Sabarmati, Mahi, Narmada and Tapi rivers) is projected to increase by 20%–40% in coming decades (RCP8.5 scenario; Shah & Mishra, 2018).



Land use in western India is dominantly agricultural and dry fallow land (Nayak & Mandal, 2012). Dry deciduous (miscellaneous) forests occur in the Aravalli Mountain ranges and the wildlife sanctuaries of Kuchchh and Saurashtra and dense forest remains in parts of south Gujarat in the Western Ghats, which has some designated biodiversity hotspots (State of Environment Report, 2015; Figure 2a). The population of Rajasthan and Gujarat has increased sevenfold since the 19th century from 20 million in 1900 (10.3 and 9.1 million, respectively) to 32 million in 1950 (15.9 and 16.3), 68 million in 1980 (34.2 and 34.1), 107 million in 2000 (56.5 and 50.7) and 141 million in 2021 (80.8 and 60.4). Stress on water resources is especially pronounced in rapidly growing urban areas. Gujarat is the third largest dam builder state of India, after Maharashtra and Madhya Pradesh (National Register of Large Dams, 2018). Of the 632 dams, 12 are currently under construction and 150 are more than 70 years old (National Register of Large Dams, 2018). Of the 212 dams in Rajasthan, 204 range from 10 to >50 m high, and eight further dams are under construction (National Register of Large Dams, 2019). In spite of these large water retention structures, groundwater supplies about 90% of water demand for irrigation (https://docslib.org/doc/8839204/rivers-of-gujarat).

Our case study catchment, the Sabarmati River, is a dryland river that flows from Rajasthan to Gujarat (Figure 3). It drains an area of around 20,000 km^2. Average annual rainfall in the basin is ~800 mm, with between 5 and 20 days rainfall intensity of 20–50 mm/day per year (Jain et al., 2017). Most reaches flow within confined and partly confined valley settings, with fully alluvial, laterally unconfined reaches restricted to short sections in low-relief lowland plains downstream of Ahmedabad (Sonam et al., 2022). Relatively steep and confined upland reaches provide refuge for biodiversity such as birds and fishes (Banyal & Kumar, 2017). The green belt within the ravines developed along river corridors in Gandhinagar and upstream reaches serve as wildlife habitat for fauna such as snakes, frogs, porcupines, wild boar, blue bull (Nilgai), monkeys, deer, peacocks, sloth bears and panthers. River health deteriorates significantly in downstream reaches due to anthropogenic impacts upon the flow regime, water pollution and altered riparian vegetation (Haldar et al., 2014; Sonam et al., 2022). Physical habitat and biodiversity are especially degraded adjacent to, and downstream of, Ahmedabad city (Figure 3), in part associated with legacy effects of textile industries, tanneries and sand extraction.

The Sabarmati River has been the heart and soul of Gujarat for centuries, directly supporting the two major cities—Ahmedabad and

FIGURE 2 Physiographic and climate attributes of Rajasthan and Gujarat. (a) 30 m resolution elevation distribution derived from SRTM mission (https://opentopography.org/). Major physiographic domains are shown—Aravalli Ranges, hinterlands, alluvial plains, estuaries, the Western Ghats, Kuchchh and Saurashtra, (b) annual average rainfall across the region (1970–2000; https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/joc.5086), (c) spatial distribution of summer temperature (1970–2000; https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/joc.5086). [Color figure can be viewed at wileyonlinelibrary.com]

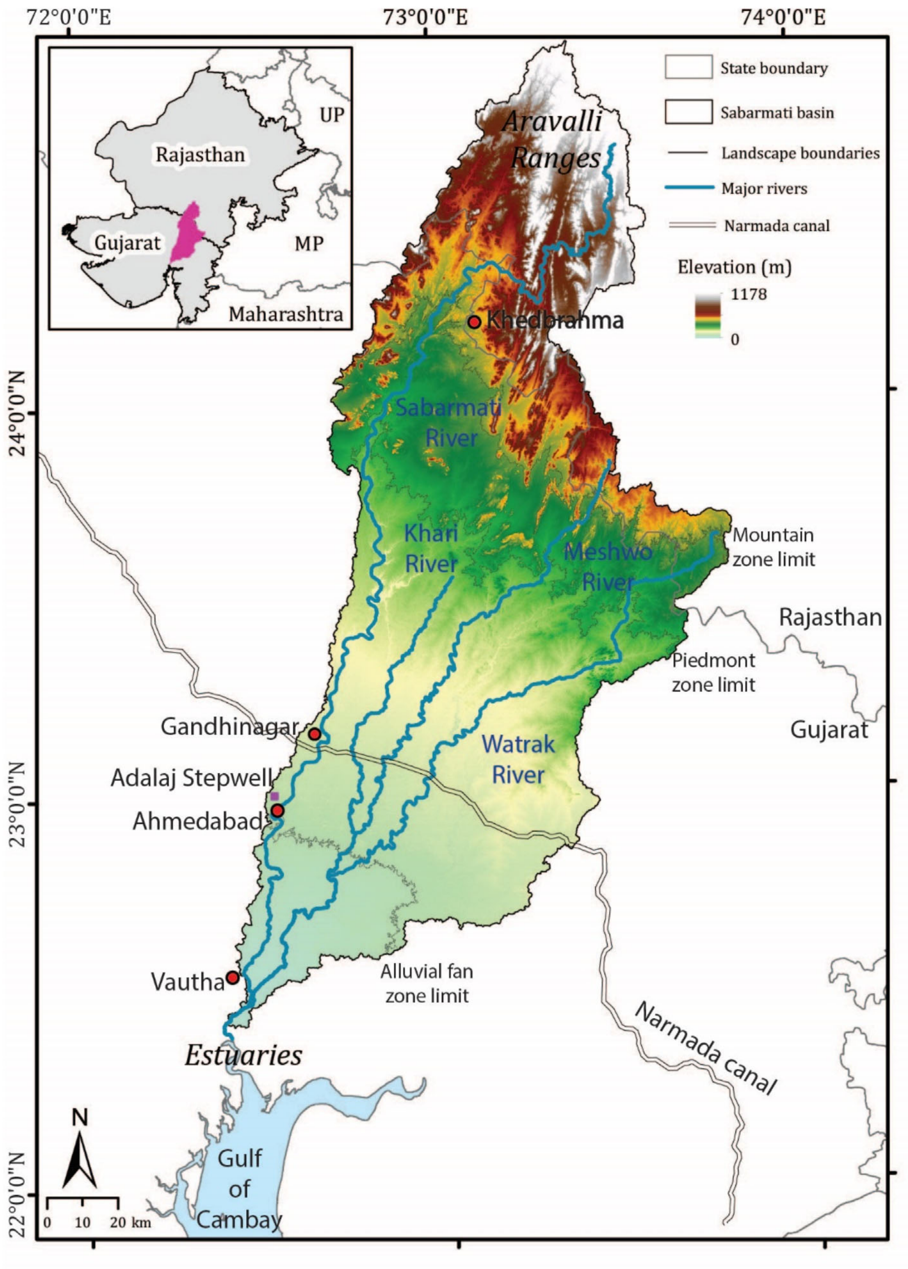


FIGURE 3 Elevation and physiographic setting of Sabarmati River basin, situated within the states of Rajasthan and Gujarat (inset). Key locations referred to in the text are indicated. [Color figure can be viewed at wileyonlinelibrary.com]

Gandhinagar (Figure 4). Prior to colonial times, Ahmedabad old city was spread mostly on the eastern banks of the Sabarmati River, in the transition zone between entrenched sections incised within terraces and alluvial reaches (Figure 3). The navigability of the river promoted the siting of Ahmedabad as a walled city in 1411 CE. Water availability exerted a major influence upon subsequent settlement and trading practices, supporting farming practices and the development of a major textile industry in the 'Manchester of the East'. Today, Ahmedabad is the seventh largest metropolis in India (population of ~8 million). Historical sites such as Gandhi's ashram, traditional water storage facilities and 16th century temples exemplify locally managed water conservation practices that reflect and express deep respect for water bodies in this arid region.

Various recent water management initiatives support water supply (primarily for irrigation) and flood control in Sabarmati catchment, including dams and barrages, interbasin transfers and canal construction (e.g., Dharoi Dam, 1976; Narmada Canal, 2008; Figure 4). With a flow capacity of 1122 m^3/s at the canal inlet, the 458 km long Narmada canal system (Figure 3) is one of the largest lined irrigation canal and interbasin river transfer systems in the world (Narmada Control Authority Annual Report, 2014–2015). Some water from Narmada Canal supports the recently created Sabarmati Riverfront Park in Ahmedabad (2015). Notionally, excess flows from the Narmada Canal flush out effluent and sludge. Concrete embankments reduce flood risk and provide a space for community engagement. However, development of the Riverfront Park displaced floodplain dwellers, and formation of a year-round pond has failed to protect lotic biodiversity (Kumar et al., 2012). Downstream water quality remains highly polluted, and riverine biodiversity is poor due to the pressure of urbanisation and industrialisation (Khatri

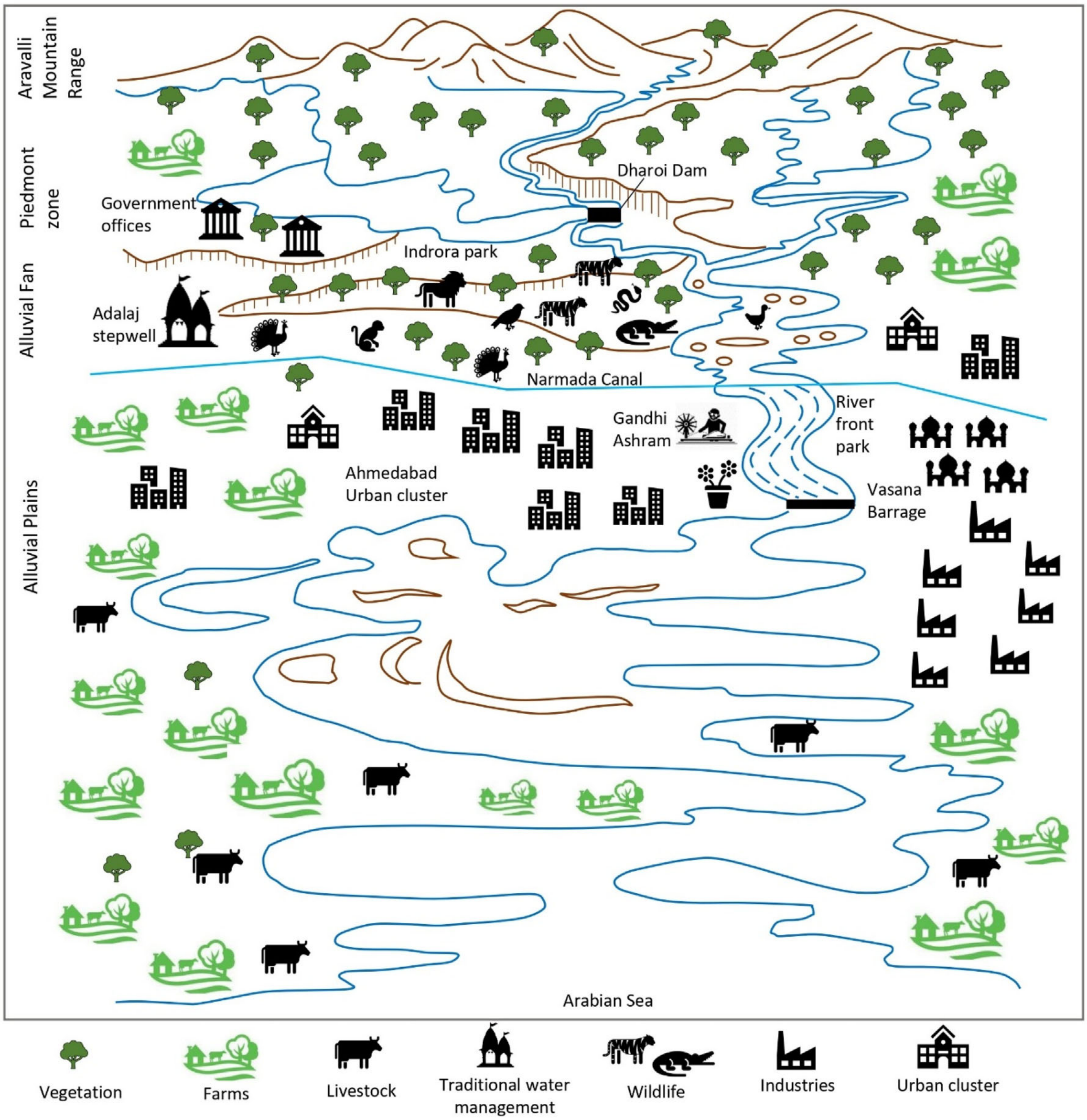


FIGURE 4 Schematic representation of contemporary socio-cultural human–river relations in the Sabarmati basin. Marked variability in land use is evident in the Aravalli Ranges relative to the piedmont zone, the alluvial fan and the alluvial plains. Urban and industrial development are accentuated in lowland reaches, serviced by water supply both upstream (Dharoi Dam) and externally (Narmada Canal). Vasana Barrage supports the Riverfront Park that links Ahmedabad and Gandhinagar. [Color figure can be viewed at wileyonlinelibrary.com]

et al., 2020; Shah & Joshi, 2017). Severe land degradation and saline water ingress significantly impact estuarine biodiversity (https://docslib.org/doc/8839204/rivers-of-gujarat).

3 | HISTORICAL CHANGES TO HUMAN–RIVER RELATIONS AND WATER MANAGEMENT PRACTICES IN WESTERN INDIA

3.1 | Traditional water management practices

Rivers have been focal points of social and religious traditions in the Indian subcontinent for millennia (Singh et al., 2020). Archaeological and historical structures indicate and reflect the geographic specificity of water management strategies and engineering designs in ancient and historical times (from around 2500 BCE through to the 17th century; Figure 5). Place-based traditional water harvesting practices transferred and stored water in different parts of these dryland landscapes (Vyas, 2011). This supported the emergence of hydraulic civilisations such as the Harappan civilisation in the Indus-Sarasvati River valleys (Danino, 2010, 2013; Giosan et al., 2012; Singh et al., 2017). Mohenjo-Daro, possibly the largest Harappan city, has been referred to as the city of *wasserluxus* or 'water splendour' (Jansen, 1993). Located close to the Indus River, there is no evidence for major water retention structures in the city. Rather, the city boasted over 700 wells, both public and private, with an average household distance to a well of around 35 m (Jansen, 1993). Among numerous

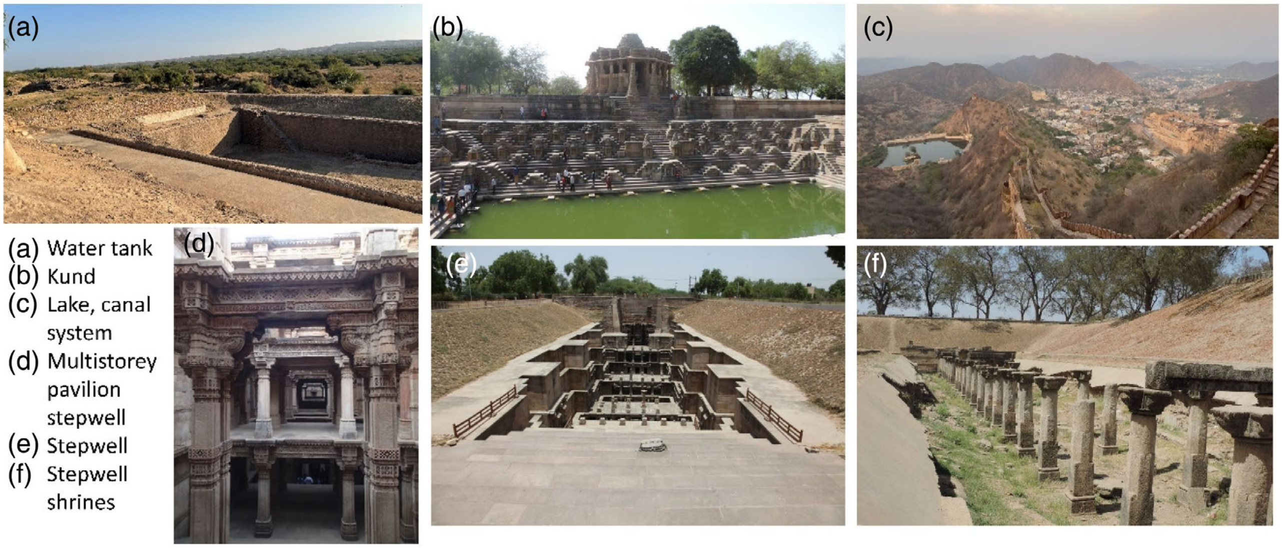


FIGURE 5 Examples of traditional water harvesting practices that supported sustainable relations to water in arid and semiarid regions of western India. (a) Water tank at the entrance of the citadel in the Harappan city of Dhoravira in the Rann of Kuchchh (3000 BCE). An integrated water system comprised at least six large reservoirs, the largest measuring 73 × 29 m and at least 10 m deep, connected by underground channels (Photo: Rahul Kaushal). (b) 10th Century kund water storage lake at Modhera Sun Temple used for ritualistic purposes and growing flowers for temple offerings (Photo: Sonam). (c) 15th Century multipurpose water facility at Amer Fort, Rajasthan where a lake fed by canals supports irrigation, fish catching, drinking, washing and bathing (Photo: Sonam). (d) 15th Century multistoried pavilions on the western bank of the Sabarmati River at Rudabai Stepwell, Adalaj Village, Ahmedabad (Photo: K. Fryirs). (e) 11th Century subterranean architecture of the Rani-ki-Vav stepwell at Patan on the southern bank of the lost Sarasvati River about 1 km from the dry channel bed (Photo: Sonam). (f) Sahastralinga water structures with small shrines installed on pillars at the water storage structure in Modhera where the buffer area of Rani-ki-Vav stepwell supported irrigation of adjacent farmlands (Photo: Sonam). [Color figure can be viewed at wileyonlinelibrary.com]

sophisticated adaptations, trapezoidal bricks were designed to withstand high pressure from underground infiltration in efforts to prevent inward collapse of wells. At Dholavira, a major Harappan city located in the Rann of Kuchchh, a complex water supply and storage network was developed along smaller seasonal streams in the early historic period (Kshatrapa; Figure 5a; Bisht, 2004, 2007). Check dams across smaller streams are also evident at Pitalkhora and Kanheri caves in the Western Ghats (3rd c. BCE). At Sahastralinga Talav (Patan, Gujarat), a series of channels diverted water from the nearby Sarasvati River into a circular settling pond (11th c. CE). Stream size influenced socio-cultural relations and water management practices (Kondolf & Pinto, 2017; Parrinello & Kondolf, 2021), with markedly different practices at Mohenjo-Daro (at least 200 ha, population 50–70,000) and Dholavira (48 ha for the fortified area, population 10–15,000) relative to smaller villages. An arid phase around 4200 years ago induced variable adaptations by different communities along the Sarasvati River, including changes to agricultural practices in some instances and abandonment of some cities in the central basin (people moved northward, towards water sources from the Siwaliks, or eastward, into the Ganga River basin; Giosan et al., 2012, 2018).

Historical records provide further insight into changing water management practices in the region. Sudarshana Lake near Junagarh, mentioned in the Girnar Rock Cut inscription of Asoka, Rudramanan and Skandagupta, was created to mitigate dependency upon monsoonal rains through development of water storage facilities to meet the agricultural demands of the region during Chandragupta Maurya (3rd c. BCE; Jain et al., 2022). Repeated destruction and repair of the reservoir indicated vulnerability of these facilities during the times of Rudradaman (2nd c. CE) and Skandagupta (5th c. CE; Bandyopadhyay, 2017).

The diversity of water management facilities and water conservation structures reflect sophisticated, regionally distinctive adaptations to 'living with' dryland rivers (Figure 5b–f). Starting around the 10th century, elaborate stepwells served multiple purposes: access to water, possible water harvesting, a cooler place for societal gathering, and often an artistic exuberance (Mishra et al., 2019). Subsequent formation of more centralised, purpose-built facilities to support traders, pilgrims and the local community continued to reflect deep connection to, and dependence upon, water (Table 1). Alongside locally designed and adapted water harvesting schemes, intricately designed water conservation structures such as bawadis or baoris (stepwells), tankas (tanks) and kunds (small reservoirs) are integral parts of ancient water storage networks in the cities of Rajasthan, Gujarat and adjacent arid areas (Figure 5; Bunce, 2013; Jain-Neubauer, 1981). Physical evidence remains for at least 45 stepwells, of various sizes, epochs and styles in and around the twin city of Ahmedabad–Gandhinagar (Joshi, 2017). Small embankments along steep channels in the Aravalli Ranges facilitated efficient infiltration of surface runoff into river beds during smaller spells of flashy rains

TABLE 1 A historical overview of changing socio-cultural relations to waterbodies in western India.

Timeline	Contextual considerations, socio-cultural relations and impacts upon river systems
2500 BCE until 16/17th century CE	Day-to-day relations to water supported low population numbers and agricultural facilities along major rivers. Sophisticated water transfer and storage networks work with nature to support major urban centres such as Dholavira and Mohenjo-Daro (Nair, 2000). Facilities support navigation (Majumdar et al., 1950). Various cultural events and rituals celebrate connections to water (e.g., worship, festivals, education programmes in ashrams).
10th century to colonial times	Growing urban centres maintain respect for waterbodies through aesthetic and religious sentiments, integrated into art and architecture (Agarwal & Narain, 1997; Chakravarty et al., 2006). Purpose-built facilities support traders, pilgrims and local communities. Stepwells, temples and tanks and vegetation management programmes facilitate well-being, including management of microclimates.
Colonial rule: From C16-18th through to 1947	External colonial assertions of a 'Rivered Eden' (Beattie & Morgan, 2017) impose a command-and-control ethos through top-down frameworks that separate humans from river systems. Focus on trade to amass wealth (e.g., East India Company) promotes state control over irrigation, navigation and drainage networks at the expense of people's customary rights. Dams and water management programmes altered flow regimes and channel morphodynamics. Extensive irrigation networks modify floodplain and wetland areas.
1947-present	Maintenance of a command-and-control ethos, under different auspices, further disconnects local communities from water supply and maintenance facilities (i.e., dependence upon 'others'). Additional acts strengthen state control over surface water at the expense of people's customary rights. Hydroelectric dams (the 'temples of India'), canals, tube wells and interbasin transfer programmes support agricultural development and industrial and urban expansion. For example, the Indira Gandhi Canal transfers water from the Sutlej and Beas Rivers in the Himalayas to parts of Rajasthan, while the Narmada Canal transfers water from Peninsular India to Gujarat. Pollution and overexploitation of resources (including groundwater reserves) present profound socio-ecological problems. Rapid population and urban growth, and industrial development, have profound consequences for societal well-being. Despite this, major festivals and religious activities continue to celebrate historical connections to waterbodies.

(Vyas, 2011). Canals built in the 10th century on the hilly outskirts of cities diverted limited rainwater into excavated tanks. This allowed water to percolate into the ground, raising the water table and recharging a deep and intricate network of aquifers which maintained base flows to rivers (Shrestha, 2019).

These various river management practices highlight the rich history of traditional knowledge that underpins socio-cultural relations to rivers and associated water management practices in western India (Table 1; Figure 6a). *Traditional knowledges in-place* applied nature-based solutions that adapted to changing circumstances in ways that lived with variability (WWAP, 2018). Strong and well-connected grounded knowledges were shared and contextualised in relation to other local knowledges and experiences (shown by the linking lines in Figure 6a). Integrated, fit for purpose water management practices supported urban populations, irrigation practices and various rituals in these dryland environments (Nair, 2000; Singh et al., 2020). Catchment-framed programmes emphasised hydrological linkages between forests, hills, springs and aquifers to conserve water and reduce evaporation (Vyas, 2011). Ancient scriptures express deep respect for water (Krishna, 2017; NIH Report, 2018; Sharma & Shruthi, 2017; Singh et al., 2020). Various festivals and rituals celebrate the life-giving, life-supporting properties of water (Table S1). River cultures expressed reverence and asserted divine status for the healing power of rivers (Singh et al., 2020; Sridhar et al., 2015). Similar relations to water and development/use of traditional knowledges are expressed in many other parts of the world (e.g., Africa, Leal Filho et al., 2022; Nepal, Joshi, 2022).

3.2 | Colonial approaches to water management in India

Integrated approaches to water management in India, and the knowledge structures that underpinned them, were profoundly disrupted when colonial rule in the 18th–19th centuries transformed relationships and practices (Table 1; Cullet & Gupta, 2009; D'Souza, 2006; Mukundan, 2005; Srinivasan, 1991). Paralleling transformations elsewhere in the British Empire (e.g., Aotearoa New Zealand; Parsons et al., 2021; Stewart-Harawira, 2020), colonial assertions of a *Rivered Eden model* sought to impose human authority over rivers (Figure 6b; Beattie & Morgan, 2017; cf. rivers of empire, Worster, 1992). Considerable technical prowess came to the fore in this era of 'command and control' (Holling & Meffe, 1996). Tasked to make rivers more uniform and predictable, engineers applied theoretical principles of hydraulic efficiency to facilitate water security (Lacey, 1930). Equivalent transformations in practice, of profound scope, scale and rate of change, accompanied the uptake of hard engineering applications in many other parts of the world. Provision of water and energy through command and control engineering programmes supported and underpinned growing populations (especially in urban areas) and industrial and agricultural developments in western India. However, externalised relations created a dependency upon others in the supply of water of an appropriate quantity and quality for agricultural, industrial and urban uses (Gupta & van der Zaag, 2008; Pradhan & Srinivasan, 2022). The suppression, elimination and weakening of local knowledges (Figure 6b) and the decoupling of relationships between

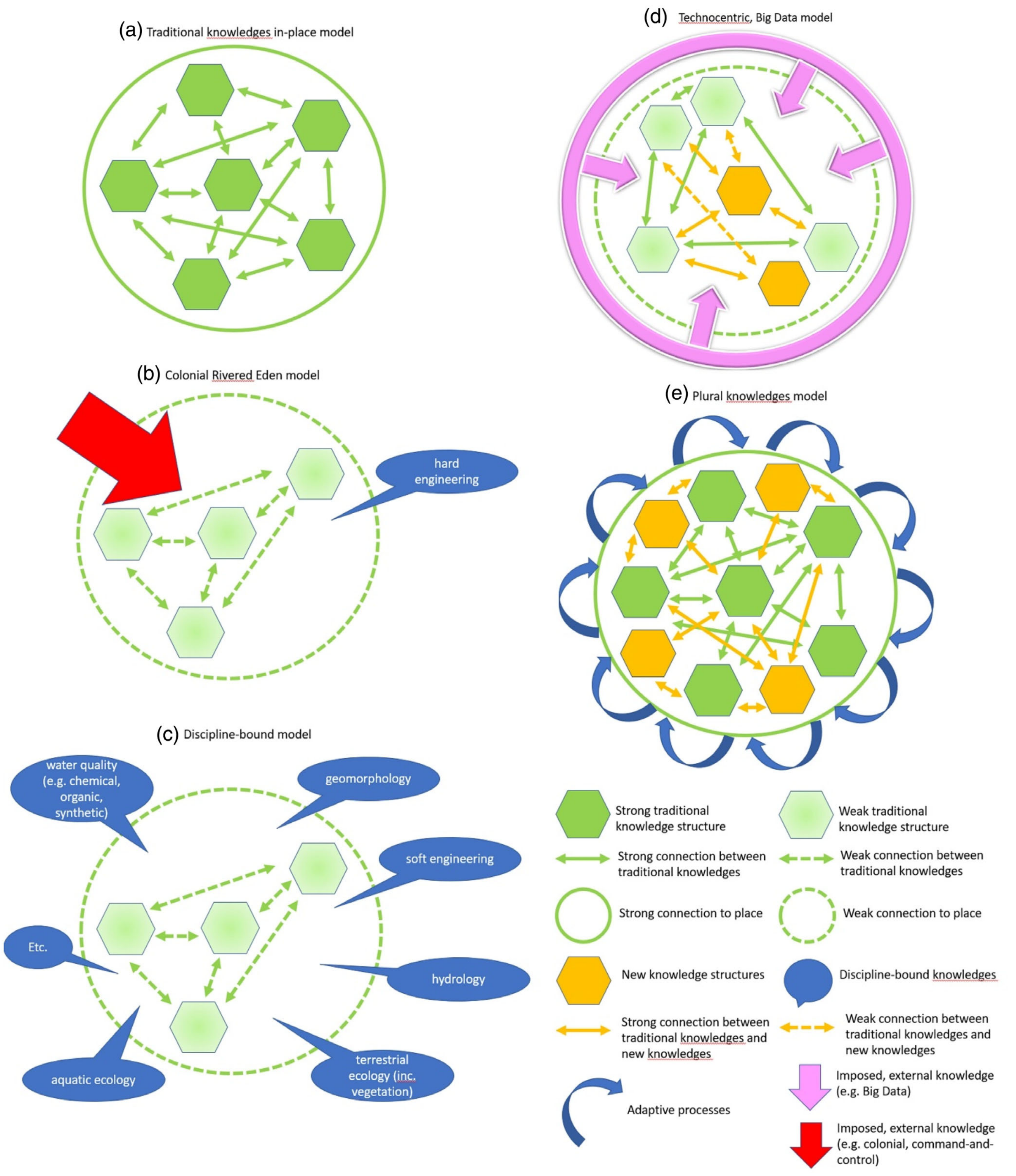


FIGURE 6 Schematic conceptualisation of changing knowledge structures that reflect historical changes in socio-cultural relations to rivers in western India. (a) Traditional knowledges-in-place (green hexagons) shows locally adapted but shared (interconnected) water management practices. (b) Colonial assertions of a Rivered Eden disrupt connections to place (shown by dotted green circle) through external imposition of a command and control ethos dominated by hard engineering principles. Links between knowledge structures were also disrupted (dotted green arrows). These practices were extended postindependence. (c) Fragmented knowledges underpin discipline-bound approaches to river repair that maintain weak connections to place. (d) Big Data add new knowledge structures (yellow hexagons) to the traditional knowledge base, accentuating potential to reconnect to place. Pink arrows indicate potential dangers of externally derived approaches. (e) A plural knowledges model that reintegrates new and traditional knowledge structures (green and yellow arrows). Blue arrows express adaptive processes that update the knowledge lens. [Color figure can be viewed at wileyonlinelibrary.com]

in-place local knowledge and water resource management practices, alongside population growth, industrial developments and land use changes profoundly altered the physical structure, flow regime and ecological functionality of rivers (Bhaumik et al., 2017). Impacts on river health, in turn, modified socio-cultural relations with rivers (Ballabh & Singh, 1997; Pearce, 2018).

Command and control management is a top-down mentality that reflects a particular subset of socio-cultural aspirations and relations to rivers. Technocentric, discipline-bound engineering principles embedded values of a water ideology that negated traditional practices and associated concerns for societal inclusion and participation (Swyngedouw, 1999). Pushing aside and silencing the rich history of traditional knowledges gained through lessons learnt in response to changing climatic and societal conditions over thousands of years disrupted the long-standing ontological coherence of hydrosocial practices (Figure 6b; Wesselink et al., 2017; Yates et al., 2017). In relative terms, at least, these impacts diminished socio-economic progress. Prior to British control, the Indian subcontinent accounted for more than a quarter of the world's economy, but after centuries of exploitation, its share has plummeted to 3% (Lent, 2021, p. 353; see also, Tharoor, 2016).

3.3 | Postcolonial relations to water: Dams as the temples of modern India

Approaches to water utilisation following independence in 1947 extended assertions of a command and control ethos (Table 1). Major inter-basin transfer and hydroelectric schemes accompanied the post-independence changes in governance structure from various princely states to larger states and one federal government. This facilitated water and energy needs for pronounced population growth and growing industries, transferring 'surplus' water to water deficit areas (Ali, 2004; Bagla, 2014; Thatte, 2007). Inevitably, approaches to modernisation reflected and asserted values of the traditional elites (Swyngedouw, 1999). Recent contemplations upon large infrastructure megaprojects, such as large dams to facilitate water transfer schemes and capitalist irrigation projects in India (Molle et al., 2009; Shah et al., 2021), reflect upon the moralisation of hydraulics through assertions of command-and-control practices (Shah & Boelens, 2021). Boelens et al. (2023, p. 18) contend that '(t)he Indian water sector is still driven by the hydraulic mission that combines scientism, an anthropocentric domination-of-nature ideology and technology as cure-all'. High profile, increasingly vociferous anti-dam movements in India express concerns for human rights, indigenous peoples and environmental concerns (Cortesi & Joy, 2021).

The push for further industrialisation and growth accentuated pollution problems and over-exploited resources (Rajput et al., 2017), with profound socio-cultural and environmental consequences (CPCB Annual Reports, 2020; Sengupta & Pandey, 2021). Changes to flow and sediment regimes impacted upon the availability and viability of habitat, biodiversity values and river health (Dutta et al., 2020; Kumar et al., 2012). Use of rivers as conduits for waste products further disconnected society from day-to-day relations to waterways (Hamner et al., 2006). Unsustainable outcomes and the historical imprint of legacy effects created path dependencies that are increasingly difficult to revoke, as an era of 'modern technicism' came to replace traditional eras of 'life environmentalism' (cf. Kada, 2006). An almost hegemonic ideology of national development, revival and progress that embodied the role of the state as master hydraulic and socio-environmental engineer sought to address concerns for water security, inevitably and inextricably tying 'nature' to the choreography of power (Swyngedouw, 1999, pp. 456, 458).

3.4 | Late C20th efforts to address the damage done

In recent decades, awareness of environmental problems and efforts to address them have come to the fore across western India (Patra & Krishna, 2015). However, associated restoration programmes have been framed and applied through a *discipline-bound model*, in both scientific and institutional terms (Figure 6c). Such reactionary and ad hoc responses to environmental damage fail to develop and apply the coherent, integrated knowledge and guidance that is needed to manage rivers as complex, interconnected and adaptive systems, in-place (e.g., Benda et al., 2002). In part, failure to embrace the prospect and promise of an era of river repair in managing dryland rivers of western India reflected the dysfunctional suite of governance arrangements (Brierley & Fryirs, 2008). While the overarching emphasis of government policies and programmes that oversee the management of rivers has been expressed through a singular focus on 'control', associated policies and institutional arrangements have been profoundly fragmented. Various national ministries liaise with State Governments in schemes to utilise and conserve water resources for purposes of flood control, irrigation, navigation, drinking water supply and waterpower development (Agarwal & Narain, 1997; Sinha et al., 2013). Jurisdictional responsibilities vary depending on the status of the land over which a river flows (Azhoni et al., 2017), with separate bodies addressing issues relating to rural and urban development and environmental concerns (e.g., pollution management, forestry, conservation and wildlife management programmes). Complex and conflicting responsibilities and agendas severely inhibit prospects for holistic approaches to sustainable river management.

3.5 | The transformative potential of a riverscape perspective, informed by modern science and Big Data

Revolutions in the availability and resolution of remotely sensed data and analytical toolkits have transformed our capacity to apply *Technocentric Big Data models* to interpret riverscapes (Piégay et al., 2020; Reichstein et al., 2019; Figure 6d; Tables S3–S5). Lack of data and technical know-how is no longer an appropriate excuse for inaction in the derivation of catchment-specific knowledge (Fryirs et al., 2021). Alongside this, growing acceptance of the need to adopt a riverscape approach recognises the imperative to apply integrative process-based understandings of hydrological, hydraulic, groundwater, geomorphic, ecological and chemical characteristics of river systems to generate coherent approaches to river science and management (Brierley & Fryirs, 2008; Dunham et al., 2018; Fausch et al., 2002). Place-based technical and scientific understandings now sit aside local and traditional knowledges, with considerable prospect to strengthen links between them (Brierley et al., 2021; Figure 6d). However, much depends upon the ways in which remotely sensed data, and associated machine learning algorithms and modelling applications, are developed and applied in-place, rather than imposed from outside or perceived as the latest panacea (Figure 6d; Fryirs et al., 2019).

3.6 | Emerging prospects: A plural knowledges approach to dryland river management

To date, a lack of proactive and precautionary plans compromises prospects that management programmes and practices work with the character, behaviour and evolutionary traits of dryland rivers in western India (Brierley & Fryirs, 2022). A *plural knowledges model* maximises the use of multiple knowledges to facilitate holistic, transdisciplinary approaches to the management of dryland rivers in-place (Koppes, 2022; Figure 6e). The distinctive properties and historical/cultural significance of traditional water management practices lie at the heart of such practices, relating local understandings to scientific understanding and Big Data applications in ways that carefully situate system-specific applications in their global (theoretical) context (Brierley et al., 2013; 2021).

What worked in the past, under one set of circumstances, may no longer be fit for purpose under circumstances that follow. Hence, strong emphasis on adaptive processes, principles and practices is required (Figure 6e). In western India, path dependencies are set by population growth and concentration in urban centres. Alongside this, profound changes to the forms and intensity of agricultural and industrial practices accompany legacy effects imposed by responses to land use changes and direct management interventions such as construction of dams and water management structures. We do not contend that simply upscaling traditional approaches will magically enable sustainable outcomes. However, much can be learnt through broader uptake of principles that underpinned such practices. Prospectively, multiple local-scale applications can reduce pressure upon top-down approaches, enhancing reliability and reducing dependency (reliance) upon others.

4 | SABARMATI RIVER CASE STUDY: A CONCEPTUAL ACTION PLAN FOR CHANGE

Drawing upon our analysis of human relationships to dryland rivers in western India, Figure 7 applies the plural knowledges model outlined in Figure 6e to support development of a conceptual action plan for sustainable management of dryland rivers in Sabarmati catchment (additional information is provided in Table S2). Our approach integrates traditional and new knowledges to enhance existing management strategies, specifically addressing interactions among complex barriers in efforts to achieve place-based outcomes in alignment with the UN Sustainable Development Goals by 2030 (Target 6.5)—public awareness, scientific research, technical capacity, finance, political will and legislation and policy (panel [i] in Figure 7; see Vercruysse et al., 2022). Here we synthesise these barriers to sustainable river management into three key themes: (i) *evidence-based knowledge and communication*—this includes public awareness, scientific research and technical capacity, (ii) *financial investment* and (iii) *governance and institutional mechanisms*—this includes political will and legislation and policy. The conceptual Venn diagram in panel (ii) of Figure 7 links these themes to identify adaptive processes required to achieve sustainability objectives.

Traditional knowledges represented as well-connected green hexagons in Figure 7 express healthy socio-cultural relations and respect for the river (the central hexagon at the heart of the figure). For example, the location, architecture, symbolism and functionality of temples and stepwells (Figure 5) recognise, embrace and work with the life-supporting nature of rivers in this region. As indigenous people in villages have been monitoring and adapting to uncertainty and change for millennia, traditional water management structures incorporate understanding of extreme flow variability and the flashy nature of runoff. Such traditional knowledges help to break down barriers of public awareness and effective communication (barrier 1) and public policy (barrier 3). Use of local languages through approaches, such as storytelling and folk songs, enhances engagement and public participation in environmental management.

New knowledge structures shown as yellow hexagons in Figure 7 aid technical capacity (barrier 4) and scientific research (barrier 6). Knowledge structures that capture and express a riverscape lens integrate observation and modelling results pertaining to hydrology, groundwater–surface water connectivity, geomorphology and impacts of engineering structures. Potentially, a living, publicly available database (prospectively called Sabarmati Knowledge Media: a research hub that integrates insights and addresses knowledge gaps across geoscience, hydrology, ecology, social science and forestry) could synthesise and update best available insights from key institutes to support such prospects. Use of place-based scientific and technical insights alongside traditional knowledges will help to revive traditional community-based water conservation structures. For example, mapping of aquifer flow paths using modern techniques and data sets (yellow hexagons) can support planned development in river corridors that facilitates both groundwater recharge at local scales as well as reviving base flow during dry periods. Such actions will reduce pressure on centralised water storage structures such as Dharoi Dam, helping to build climate resilience at local scales.

Adaptive processes shown as blue arrows in Figure 7 act as key drivers of the *plural knowledges model*. Co-governance arrangements engage the whole community through inclusive approaches to planning and enactment of environmental policies to achieve long-term

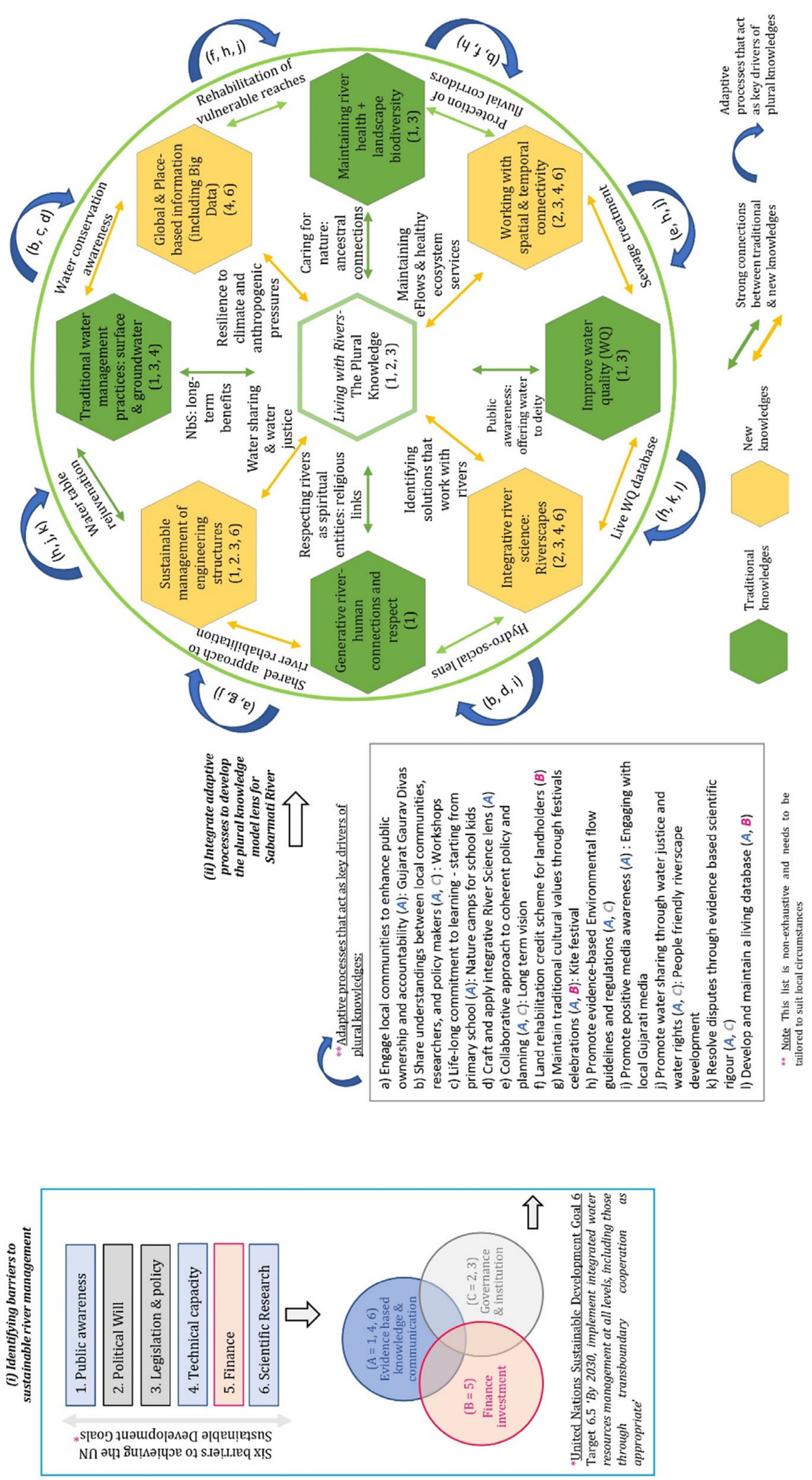


FIGURE 7 Complex interactions of traditional and new knowledges underpin a plural knowledges model to support sustainable management of dryland rivers in Sabarmati catchment. (*i*) UNSDG barriers to sustainable river management are differentiated into three categories: (A) evidence-based knowledge and communication, (B) finance investment, and (C) governance and institutions. Adaptive processes (blue arrows on [iii]) present examples of steps taken to address barriers (categorised as A, B and C). (*ii*) The plural knowledges model lens for Sabarmati River. The solid green circle conveys the generation and use of locally appropriate knowledges with new scientific knowledge to support proactive and coherent approaches to sustainable management. This synthesises traditional knowledges (green hexagons), new knowledge structures (yellow hexagons), strong connections between traditional knowledges (green arrows) and strong connections between traditional and new knowledges (yellow arrows). Numbers in hexagons refer to barriers to sustainable river management (i). Adaptive processes (blue arrows; with details from ii) act as key drivers of the plural knowledges model and present examples of steps taken to address barriers (categorised as A, B and C). [Color figure can be viewed at wileyonlinelibrary.com]

visions that balance human water use needs and environmental needs (barrier 3). Governing institutions (people's representatives, barrier 2) ensure that approaches to river basin development respect culturally relevant practices of village communities. Empowering community leaders with finances and tool kits (barrier 5) to achieve a long-term (12–15 year) vision helps to create intergenerational engagement in watershed and forest management.

In biophysical terms, managing issues at source and at scale is required to protect water resources and maintain biodiversity values (Fuller et al., 2023). This entails the conservation of forest reserves in upstream mountainous areas such as Sabarkantha and Banaskantha districts (e.g., Balaram Ambaji and Jessore Sloth Bear Wildlife Sanctuary). Historically, there have been no restrictions on use of surface water resources in Sabarmati catchment. In mid-lower courses of the river, management of the environmental flow regime is required to maintain and/or enhance surface water–groundwater connectivity, channel–floodplain connectivity and improve water quality to support healthy floodplains and pasture lands. Revival of traditional water harvesting structures alongside improvements to riparian vegetation cover will enhance water availability, helping to restore hydrogeomorphic connectivity and aquatic/terrestrial biodiversity. For example, urban forestry zones and wilderness parks along river corridors such as Indrora Nature Park and on the Sabarmati River banks in Sabarkantha and Gandhinagar districts can contribute to nature-based recovery of environmental quality at the local scale. Alongside efforts to minimise floodplain encroachment and impacts of sand mining, environmental flow allocations will improve ecological functions in downstream reaches, enhancing flow connectivity to ensure groundwater replenishment, increase seed dispersal, improve soil fertility and improve water access for flora and fauna. More generative water sharing programmes ensure equitable access to water and improve river health into the future, building upon recent expansion and enhancement of the canal network that now provides water to different parts of the region (e.g., https://wasmo.gujarat.gov.in/).

From our perspective, moves to enact the plural knowledges model outlined in Figure 7 should start by raising public awareness and recognition of the tasks to be addressed, emphasising the critical role of dryland rivers as the foundation of life support systems in this region. Such prospects can build upon the success of recent high profile social movements to enhance awareness of the river and its environments (e.g., Bishnoi Movement, Rajasthan State; Narmada Bachao Andholan, Tarun Bharat Sangh led by Rajendra Singh—Waterman of India). As existing approaches to solving environmental crisis are insufficient and piecemeal, new philosophical paradigms are required to underpin moves towards sustainable development. Various major religions are in the midst of a 'green turn', drawing on elements of traditional philosophies and reinterpreting scriptural sources (Jain, 2017). Environmental conservation efforts led by Sant Balbir Singh Seechewal (aka Eco-Baba) in the Punjab exemplify new approaches to ecological consciousness and new forms of environmental governance (Jain, 2017). Effective communication—listening and sharing diverse voices that express differing relations to river systems—supports such ventures. Emerging prospects can build upon (a) various celebrations and traditional festivals that express cultural relations and religious/spiritual connections (e.g., kite festival, folk-songs, Dandi March, weekly haat and Vautha Cattle Fair; Table S1), (b) traditional water management structures (Figure 5), (c) historical connections associated with the Sabarmati Ashram and (d) generative opportunities presented by the riverfront park between Gandhinagar and Ahmedabad (e.g., Gujarat Gaurav Divas 2018). Effective use of social media can support public participation and promote activities that highlight the benefits of healthier rivers.

Building on agreement of the imperative for change, political will and associated legislation and policy are required to articulate what a sustainable approach to river management looks like, outlining how reframed institutions and collective approaches to governance and participation will support and maintain such interventions. Formalising the legal status of rivers is an integral step in the design and implementation of more visionary approaches to management of dryland rivers. This can build upon integrated watershed management programmes such as *Sujalam Sufalam Jal Abhiyan (SSJA)* implemented by the Government of Gujarat, the *Sardar Patel Participatory Water Conservation Project Scheme (SPPWCS)* in Saurashtra (Draft Gujarat State Water Policy, 2011), various water conservation initiatives (Gogna, 2021) and emerging approaches to holistic (participatory) management of groundwater resources (*Atal Bhujal Yojana* proposed by the Department of Water Resources, Ministry of Jal Shakti, involves the concerned Central and State Government machinery, Panchayati Raj Institutions, non-governmental organisations, Water User Associations, farmers and other stakeholders). Embedding visions and action strategies in policy and legislation requires cooperation between differing states and authorities, enhancing existing legislation to support integrated river and wetland management such as the Indian Forest Act (1927), the Wildlife Protection Act (1972), the Water (Prevention and Control of Pollution) Act (1974), the Environment (Protection) Act (1986), the National Water Policy (1987), the National Forest Policy (1988), Wetland Conservation and Management Rules (2017) and various forms of legislation and policies to minimise pollution (Table S2).

Considerable technical capacity is already in-hand to support more visionary approaches to sustainable management of Sabarmati catchment. However, steps are required to embed co-governance and participatory arrangements (including citizen science programmes) in more holistic and inclusive approaches to conservation and rejuvenation of rivers (cf. Jain et al., 2016; Sinha et al., 2013). Recent interventions acknowledge and seek to address this limitation. For example, top-down realignment to create the Ministry of Jal Shakti in 2019, alongside various schemes of the Ministry of Water Resources, the Central Groundwater Board, the Ministry of Rural Development (integrated watershed management and MGNREGA), the Ministry of Agriculture, the Ministry of Environment, Forest and Climate Change and the Ministry of Tribal Development highlight the imperative for enhanced cross-agency collaborations across various governing institutions in India.

Alongside this, state agencies such as the Gujarat State Land Development Corporation, Ministry of Panchatay Raj, the Water and Sanitation Management Organisation and the Ministry of Rural Development attempt to incorporate traditional water conservation and harvesting techniques to support small watershed scale rejuvenation projects. Also, local initiatives increasingly embrace Participatory Water Conservation Projects (e.g., Jadeja et al., 2018; https://www.downtoearth.org.in/coverage/river-of-joy-21356). Key state bodies in Gujarat, such as the Department of Environment and Forests, the Irrigation Department and the Gujarat Climate Change Department, can engage more generatively with university researchers and bodies such as the Indian Institute of Soil and Water Conservation (ICAR—Vasad Gujarat), Anand Agriculture University, GEER Foundation, IIT Gandhinagar in the development, enactment and monitoring of legislation and policy pertaining to soil and water conservation and watershed management (Figure S1). An appropriate resource base is required to support skill development and retraining, professional development and education initiatives and associated monitoring and adaptive management programmes. New packages of interventions can reprioritise funding and incentivise activism, further enhancing efforts to engage stakeholders and empowering gram sarpanch with finance and toolkits (Figure 7). Flow of funds from the Central and State Ministries to the local gram panchayat is required to support watershed development and management programmes across all parts of the basin. Such social and institutional interventions extend well beyond limitations of programmes that are envisaged and enacted within a singular focus on a technocentric lens (e.g., Parsons et al., 2021).

5 | DISCUSSION: A PLURAL KNOWLEDGES MODEL FOR SUSTAINABLE DRYLAND RIVERS

> The domestication of rivers, which re-orders nature and human simultaneously, has been fundamental to colonialism, hydrocracies and capitalist-modernist missionary projects worldwide. Most contemporary water management paradigms frame water as merely a calculable production factor, commodity or threat; while advocating stakeholder participation they ultimately remain wedded to expert paradigms. Techno-environmentalist approaches favor "environmental flow" programs that tend to translate river-nature into mathematical biological or physical formulae and may, again, abstract and disembody rivers. The scientific approaches that prominently feed these "inclusive (neoliberal) water policies (e.g., consultation and market-environmentalism) equally misinterpret manifold, dynamic society-nature interactions".
>
> Boelens et al., 2023, p. 23

Mindsets, positionality and inherent politics underpin approaches to the management of river futures (Tadaki et al., 2014). Profound anthropogenic transformation to river systems raises key questions about justice, wherein '(d)ifferential access to water, asymmetries in rights and uneven levels of protection and influence over decision-making are inevitably forged along lines of class, gender, ethnicity and human/non-human' (Boelens et al., 2023, p. 2). This paper documents just one region's struggle, showing how neglect for traditional, locally based water management principles and practices increasingly challenges prospects to look after distinctive values of dryland rivers in western India. Prospectively, use of traditional knowledges/wisdom that embrace river diversity and variability as part of nature-based solutions will enhance sustainability prospects, moving beyond imposed realities of an anthropocentric 'command and control' world (e.g., Cohen et al., 2023; Linton & Pahl-Wostl, 2023). Assertions of a Rivered Eden and the institutional arrangements that impose such ventures are far removed from the aspirational and equitable values of Mahatma Gandhi's Ashram in Ahmedabad and associated concerns for social and environmental justice. Prospects for (re)generative, transformative change entail moves to 'socialise the scientist'. The river-centric approach outlined in Figure 7 provides an aspirational lens to envisage such ventures - one that asserts the rights of the river (Boyd, 2017; Brierley, 2020; Brierley et al., 2019; Kothari & Bajpai, 2017).

Sophisticated place-based knowledge and traditional wisdom pertaining to sustainable water resources management are readily available in western India (Table 1). Conceived and enacted alongside insights derived from new and emerging datasets and modelling applications (Tables S2–S5), a plural knowledges framing can engender and embed visionary approaches to sustainable futures that work with the range of variability and evolutionary traits of each river system (Figure 7; Fernández-Llamazares et al., 2021; Ford et al., 2020). Further research is required to up-scale local scale practices, helping to defuse pressure and reliance upon top-down, externally framed applications.

Coherent proactive and precautionary catchment management plans tackle issues at-source and at-scale to address concerns for intergenerational equity and off-site impacts (distributive justice) (Brierley & Fryirs, 2022; Fuller et al., 2023). An inventory of 'exemplars of good practice' that demonstrates how and why particular approaches to local/traditional water harvesting, storage and transfer techniques work well in particular situations would support meaningful transfer of insights and applications to differing situations in western India. Beyond this, care is needed to select and adjust off-the-shelf products developed elsewhere, for quite different types of rivers in quite different environmental settings, to ensure that they are fit for purpose (Figure 6d; Fryirs et al., 2019). Mechanisms and safety nets are required to test the local reliability of information and insights derived from Big Data and associated machine learning algorithms and modelling applications (O'Neil, 2016; Oreskes et al., 1994). Field verification is vital (see Figure S2). Statements of accuracy and precision should not be confused with notions of quality, reliability and on ground (real-world) meaning (Braun, 2021). Over-generalised understandings that are not well attuned to work with the distinctive character, behaviour and evolutionary traits of dryland rivers in western India can be considered to represent a contemporary variant of externally imposed insight, essentially repeating mistakes from the past (cf. Figure 6b). Inappropriate applications can seriously compromise and undermine trust in the river management and planning process.

New institutions and governance arrangements, many of which are yet to be envisaged let alone realised, will be required to support transdisciplinary and adaptive practices that co-craft and co-implement local-scale, participatory interventions and programmes/policies that enact a *plural knowledges approach*, making best use of best available understanding and meaningfully integrating top-down institutional framings with bottom-up community-led participatory practices (Tables S1 and S2; Boelens et al., 2016; García et al., 2021; Krueger et al., 2016). Inclusive practices and grass roots initiatives co-develop and co-apply appropriately contextualised knowledges-in-place, situating local circumstances in their global context (Brondízio et al., 2021). Only time will tell whether there is wisdom to make wise use of what is known (see Wiedmann et al., 2020).

6 | CONCLUSIONS

Summary points from this paper are as follows:

1. Dryland rivers that support a significant proportion of the Earth's population and economies are especially vulnerable to the impacts of climate change and anthropogenic disturbance. This case study from western India shows how region-specific strategies that respect biophysical, socio-economic and cultural diversity are needed to inform approaches to sustainable river management.
2. Imposition of engineering-based command and control approaches to water resources utilisation in colonial times disrupted and transformed a long and rich tradition of sustainable water management practices informed by local and traditional knowledges in the arid/semiarid riverscapes of western India. Profound legacy effects and path dependences shape what is possible in management of these river systems now and into the future.
3. Although rivers provide critical lifelines in the arid/semiarid zone, degradation of hydrological, morphological, ecological and water quality conditions has induced severe stress and poor health. Profound socio-cultural disconnect from rivers has accompanied these changes.
4. An integrative approach based on the design, uptake and progressive refinement of a *plural knowledges model* that merges cross-disciplinary understandings of river sciences with local and traditional knowledges is proposed to support the sustainable development of river systems in western India.
5. New institutions are required to support transdisciplinary practices that co-create and co-implement local-scale, participatory interventions and programmes/policies that apply a plural knowledges model for sustainable management of dryland rivers in western India.

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DATA AVAILABILITY STATEMENT

SRTM DEM 30 m resolution data were obtained from http://www.earthexplorer.org. Mean annual rainfall and Summer temperature data were obtained from https://www.worldclim.org/.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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