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Assessing the feasibility of integrating ecosystem-based with engineered water resource governance and management for water security in semi-arid landscapes: A case study in the Banas catchment, Rajasthan, India

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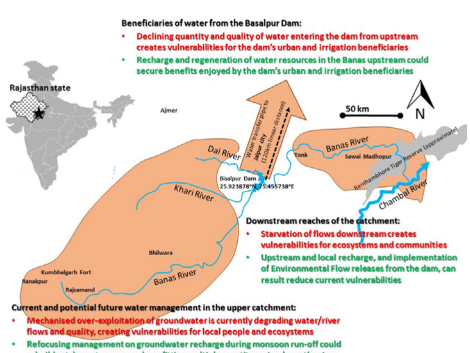
HIGHLIGHTS

- Intensive water over-exploitation drives socio-ecological degradation in the Banas.
- Historic and current schemes regenerate water resources from monsoon rains.
- A program refocused on resource recharge can benefit all catchment beneficiaries.
- Rajasthan's policy environment recognises the need to promote resource recharge.
- A systemic approach to management and investment can guide sustainable development.

GRAPHICAL ABSTRACT



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ABSTRACT

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Much of the developing world and areas of the developed world suffer water vulnerability. Engineering solutions enable technically efficient extraction and diversion of water towards areas of demand but, without rebalancing resource regeneration, can generate multiple adverse ecological and human consequences. The Banas River, Rajasthan (India), has been extensively developed for water diversion, particularly from the Bisalpur Dam from which water is appropriated by powerful urban constituencies dispossessing local people. Coincidentally, abandonment of traditional management, including groundwater recharge practices, is leading to increasingly receding and contaminated groundwater. This creates linked vulnerabilities for rural communities, irrigation schemes, urban users, dependent ecosystems and the multiple ecosystem services that they provide, compounded by climate change and population growth. This paper addresses vulnerabilities created by fragmented policy measures between rural development, urban and irrigation water supply and downstream consequences for people and wildlife. Perpetuating narrowly technocentric approaches to resource exploitation is likely only to compound emerging problems. Alternatively, restoration or innovation of groundwater recharge practices, particularly in the upper catchment, can represent a proven, ecosystem-based approach to resource regeneration with linked beneficial socio-ecological benefits. Hybridising an ecosystem-based approach with engineered methods can simultaneously increase the security of rural livelihoods, piped urban and irrigation supplies, and the vitality of river ecosystems and their services to beneficiaries. A renewed policy focus on local-scale water recharge practices balancing water extraction technologies is consistent with emerging Rajasthani policies, particularly *Jal Swavlamban Abhiyan* ('water self-reliance mission'). Policy reform emphasising recharge can contribute to water security and yield socio-economic outcomes through a systemic understanding of how the water system functions, and by connecting goals and budgets across multiple, currently fragmented policy areas. The underpinning principles of this necessary paradigm shift are proven and have wider geographic relevance, though context-specific research is required to underpin robust policy and practical implementation.

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1. Introduction

Industrial growth, technological development and capital accumulation during the nineteenth century triggered economic thinking and consequent management and technology choices that overlooked the importance of ecological processes and their contributions to public and business welfare (Braat and de Groot, 2012). Across multiple policy spheres, broader spatial and temporal negative externalities resulting from narrow framing of both problems and solutions consequently result not from bad intent but from lack of systemic perspective. Technology choices for the provision of water to urban centres, industry and irrigation exemplify this utilitarian approach, overlooking wider ramifications for the water cycle and its dependent ecosystems and livelihoods downstream of abstracted surface and groundwater resources (World Commission on Dams, 2000). Lack of systemic thinking is also contributory to state-led dispossession of water rights from rural people as a supply-side solution to support industrial and urban economic growth (Birkenholtz, 2016). Technocentric policy presumptions tend to drive engineered solutions, for example 'dam and transfer' schemes and energised groundwater abstraction, maximising a subset of uses of piped water and energy favouring influential beneficiaries whilst overlooking many linked ecosystem services and their beneficiaries (World Commission on Dams, 2000; Everard, 2013).

The integral connections between urban, rural, industrial, agricultural and nature conservation benefits provided by catchment ecosystems have often been overlooked in former management paradigms (Newson, 2008). Integrated Water Resources Management (IWRM) has been advanced as a response to meeting competing needs and uses at catchment scale (Calder, 1999), including addressing the growing problem of water scarcity in the developing world (Shah and van Koppen, 2014). Practical implementation of the principles of IWRM across extensive and diverse landscapes in developing world situations is however frequently limited by knowledge and data gaps, regulatory and scientific capacities, and power asymmetries (Ioris, 2008).

Everard (2013) identified the need and opportunities for increasing synergy between ecosystem-based and engineered water management solutions. Neither paradigm represents a panacea in mixed urban-rural landscapes, in which engineered management is far more interdependent with ecosystem processes than is conventionally recognised. Large-scale cases of landscape management for improving raw water quality, for example serving water supply to New York City (Committee to review the New York City Watershed Management Strategy, 2000), the Upstream Thinking programme in south west England (McGonigle et al., 2012) and to protect natural spring water sources in France (Perrot-Maître, 2006), demonstrate substantial economic and input efficiencies relative to conventional electromechanical treatment of more contaminated water, also producing multiple ecosystem service co-benefits.

In India, recent policy presumptions favour advanced engineering solutions that may not work in sympathy with local geography and culture, and hence may not be sustainable in the long term. These include substantial investment in large-scale 'dam and transfer' schemes, diverting water from areas of perceived excess towards urban economies and intensive irrigation centres of high demand. India's National Informatics Centre (2017) lists 4877 completed 'large dams' (as defined by the International Commission on Large Dams, ICOLD) with a further 313 large dams under construction across the country, impounding virtually all large rivers systems. The needs of people and ecosystems in donor catchments are poorly reflected in management decisions, though ramifications of physical impoundments, redirection of flows and changes in catchment ecosystem services may be profound (World Commission on Dams, 2000). Severe problems stemming from over-exploitation of groundwater have long been recognised, including depletion of water tables, saltwater encroachment, drying of aquifers, groundwater pollution, and soil waterlogging and salinisation (Singh and Singh, 2002) and local risk of subsidence (Rodriguez and Lira, 2008). Nevertheless, India's policy environment still favours energised tube well abstraction of receding and increasingly geologically contaminated groundwater to promote short-term agricultural profitability (FAO, 2011). This is leading to abandonment of centuries-long, geographically and culturally sensitive practices and loss of associated traditional wisdom balancing water access with recharge from episodic monsoon rainfall (Das, 2015; Raju, 2015).

This paper addresses vulnerabilities created by fragmented policy measures between rural development, urban and irrigation water supply, and downstream consequences for people and wildlife. Water vulnerability is a multi-factorial issue, comprising water scarcity, generally assessed on a volumetric basis, and water stress which includes factors such as water quality, accessibility and the commonly underestimated influence of governance arrangements and other social factors (Plummer et al., 2012). Water vulnerability is therefore a dynamic concept integrating geographical and climatic factors with demand, infrastructural conditions and prevailing institutional arrangements,

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