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Water security and rainwater harvesting: A conceptual framework and candidate indicators

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ABSTRACT

Rainwater-harvesting tanks (reservoirs) in Tamil Nadu, India support agricultural livelihoods, mitigate water insecurity, and enable ecosystem services. However, many tanks have fallen into disrepair, as private wells have supplanted collectively managed tanks as the dominant irrigation source. Meanwhile, encroachment by peri-urban development, landless farmers, and *Prosopis juliflora* has reduced inflow and tank capacity. This exploratory study presents a conceptual framework and proposed indicator set for measuring water security in the context of rainwater harvesting tanks. The primary benefits of tanks and threats to their functionality are profiled as a precursor to construction of a causal network of water security. The causal network identifies the key components, causal linkages, and outcomes of water security processes, and is used to derive a suite of indicators that reflect the multiple economic and socio-ecological uses of tanks. Recommendations are provided for future research and data collection to operationalize the indicators to support planning and assessing the effectiveness of tank rehabilitation.

1. Introduction

Rainwater harvesting techniques have long been implemented around the world to cope with inter-annual variability in precipitation and maintain human well-being. Predominantly applied in semi-arid regions, decentralized techniques such as pits, terraces, ponds, check dams, sand dams, small reservoirs, cisterns, and open wells have been used to mitigate water and food insecurity (Akpinar Ferrand & Cecunjanin, 2014). In the South Indian State of Tamil Nadu, smallholder agriculture depends on irrigation provided by thousands of small rainwater harvesting reservoirs, known regionally as tanks. Tanks in Tamil Nadu account for approximately 18% of crop irrigation water (DES, 2011) and generate a multitude of benefits, including increasing and moderating agricultural production, alleviating poverty, and providing ecosystem services.

However, broad-scale changes in climate, urbanization, and technology are negatively affecting local-scale water security provided by tanks. Researchers and farmers have described changes in the timing, duration, and intensity of the Northeast monsoon (October–December) that provides up to 50% of regional annual precipitation, and influences decisions regarding planting and crop type (Pal & Al-Tabbaa, 2010). Urbanization and invasive vegetation are consuming land occupied by tanks and inhibiting inflow. Meanwhile, the proliferation of private groundwater extraction has led to investment declines in tank maintenance (Kajisa, Palanisami, & Sakurai, 2007). Such threats to the security of collectively managed water systems are not unique to Tamil Nadu, and occur in various forms across semi-arid regions of Asia, the Middle East, and Africa (Biazin, Sterk, Temesgen, Abdulkedir, & Stroosnijder, 2012; Geekiyanage & Pushpakumara, 2013; Hussain, Abu-Rizaiza, Habib, & Ashfaq, 2008; Molle, Shah, & Barker, 2003; Vohland & Barry, 2009).

Water availability is the most important consideration for Tamil Nadu farmers regarding what, when, and how much to plant in a season. Given the importance of tank irrigation to agricultural livelihoods, reliable measures of the provisioning characteristics of tanks could enable a baseline assessment of water security, provide advance warning when water security approaches a critical threshold, and evaluate the performance of tank restoration investments. The objective of this paper is to develop a set of water security indicators in the context of smallholder agriculture and rainwater harvesting tanks. To do so, we combine field observations and literature review to identify the core determinants and

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processes that influence water security, and model them using a causal network. We define water security in this context as the sufficient availability and equitable access to water as an input to agricultural production and associated human well-being.

The remainder of the paper is organized as follows. Section 2 describes the functions, benefits, and threats rainwater harvesting tanks in Tamil Nadu. Section 3 reviews existing frameworks that address water security themes in an agricultural context. In Section 4, we construct a causal framework of the system and use it to develop a suite of water security indicators. Section 5 concludes with recommendations for further investigation of water security in tank systems.

2. Tank systems of Tamil Nadu

For millennia, people in Tamil Nadu have used rainwater-harvesting tanks to capture, store, and deliver water-related services to local villages. Tanks are small reservoirs primarily used for crop irrigation, and were a central driver of early settlement patterns across South India. Tanks are constructed across natural depressions in the landscape, impounding water from rivers or storm runoff behind crescent-shaped earthen embankments called bunds. Sluice gates control the flow of tank water through the bund to irrigated fields downgradient in the command area. Water user associations comprised of local stakeholders collectively maintain and manage tanks, with responsibilities including distributing water among users, desilting the tank bed, and clearing supply channels (Kajisa et al., 2007). Many tanks are linked in cascades, with overflow channels providing connections to downstream tanks, forming a complex hydrologic network of manmade wetlands across the landscape (Geekiyanage & Pushpakumara, 2013; Van Meter, Basu, Tate, & Wyckoff, 2014). These tightly-coupled human and natural systems coevolved over time, as the monsoonal precipitation patterns characteristic of the region required storing water to sustain agricultural production, which in turn profoundly modified the landscape. Today, rural Tamil Nadu is a dense network of intensively farmed land and home to nearly 40,000 tanks (Fig. 1), comprising 17% of all tanks India (Amarasinghe, Palanisami, Singh, & Sakthivadivel, 2009).

2.1. Benefits

Tanks provide an array of economic, environmental, and socio-cultural benefits to farmers and villages (Ariza, Galán, Serrano, & Reyes-García, 2007). Among the leading economic benefits are significant improvements in agricultural yield (Table 1), and greater

Table 1
Major crops and water requirements in Tamil Nadu (DES, 2011; Krishna, 2010).

Crop	Water requirement (mm/ha/yr)	Yield (Kg/Ha unless otherwise noted)		Yield gain
		Rain fed	Irrigated	
Sugar cane	1500–2500	–	101[a]	–
Rice	900–2500	–	3070	–
Cotton	700–1300	333	456	37%
Maize	500–800	3264	6384	96%
Groundnut	500–700	1435	3377	135%
Chilli	500–700	534	–	–
Sorghum	450–650	830	1808	118%
Black gram	400–600	380	–	–
Green gram	400–600	345	–	–
Pearl millet	400–450	1379	2635	91%
Finger millet	400–450	1781	3188	79%

[a] Cane-tonnes.

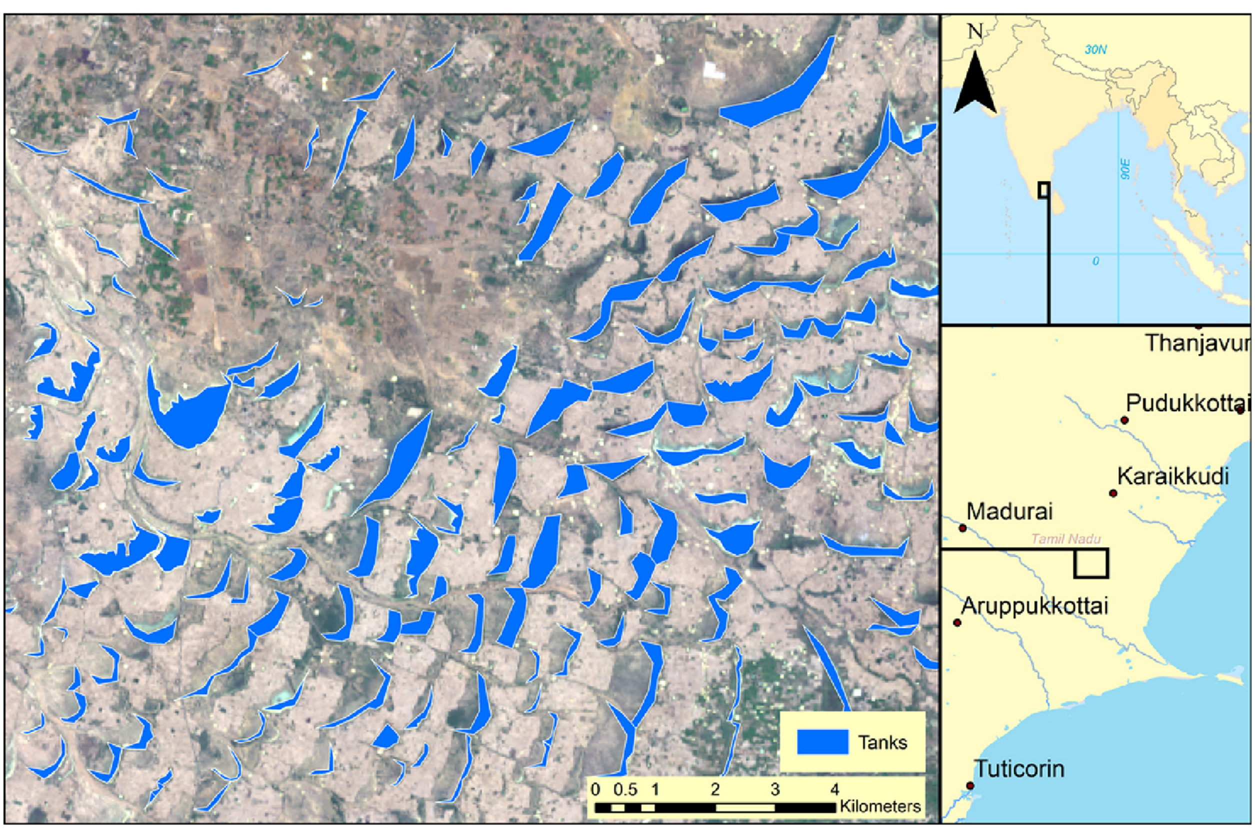

Fig. 1. Rainwater harvesting tanks across the Tamil Nadu landscape.