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Spatial Patterns of Tank Decline and Rejuvenation in the Kaveri River Catchment, South India

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Summary

Irrigation tanks are an ancient method of water management in South India that rely on the capture and storage of monsoon rain. The use of tanks has declined dramatically in modern times, though recent pressures of water scarcity have resulted in a resurgence of tank irrigation. This paper uses GIS and remote sensing techniques to investigate the spatial patterns of tank decline and rejuvenation in the Kaveri River Catchment, building a greater understanding of the lasting effect of historic irrigation policies on the contemporary geographies of tank irrigation in South India.

KEYWORDS: Water, LISA, MNDWI, Historical Maps, Spatial Humanities

1. Introduction

Tank irrigation has been used across South India since ancient times (Ramesh 2018). Irrigation tanks are artificial lakes that can operate individually (rain-fed tanks), or in chains connected to rivers or canals (system tanks; Palansami et al. 2010). Tanks capture and store rainwater during ‘wet seasons’, spending some of the year dry to provide fertile silt for agriculture (Parasarthi 2017). Tank irrigation has declined over past centuries, due to a variety of factors that remain a matter of debate. Mosse (2003) suggests that irrigation tanks have operated in continuous cycles of decline and rehabilitation throughout history, whereas Parasarthi (2017) and Reddy et al. (2018) argue that tank decline is a result of adjustments to economic structures and the privatisation of land during British Colonialism (1858-1947). India’s ‘Green Revolution’ (1960s-70s) is also cited as a key period for tank decline due to improvements in agricultural technologies and the increasing affordability and accessibility of groundwater (Mathevet et al. 2020; Reddy et al. 2018; Parasarthi 2017).

The rejuvenation of tank irrigation has been highlighted as part of the answer to India’s looming water crisis; functioning tanks can provide increased rates of groundwater recharge, increase well productivity, improve resilience to flooding and drought, and positively impact local biodiversity (Chowdhury and Behara 2018; Palansami et al. 2010). However, previous research is limited to localised studies, and there is little understanding of tank function on a regional scale. This paper will therefore investigate spatial patterns in the contemporary use of irrigation tanks within the southern part of the Kaveri River catchment, South India, to reveal patterns in tank decline, as well as determine the potential for future rejuvenation.

2. Methods

The locations of historical tank features for this study were found using digitised sheets from the Survey of India (SOI) first edition maps, published between 1916 and 1932 (link). These maps are held in the collection at the National Library of Scotland (NLS) and provide coverage for South India, offering valuable insights into this region’s environmental history. 2,644 irrigation tank features were identified across the study area and digitised using QGIS 3.16. The study area comprises the part of the Kaveri catchment for which these maps were available (**Figure 1)**.

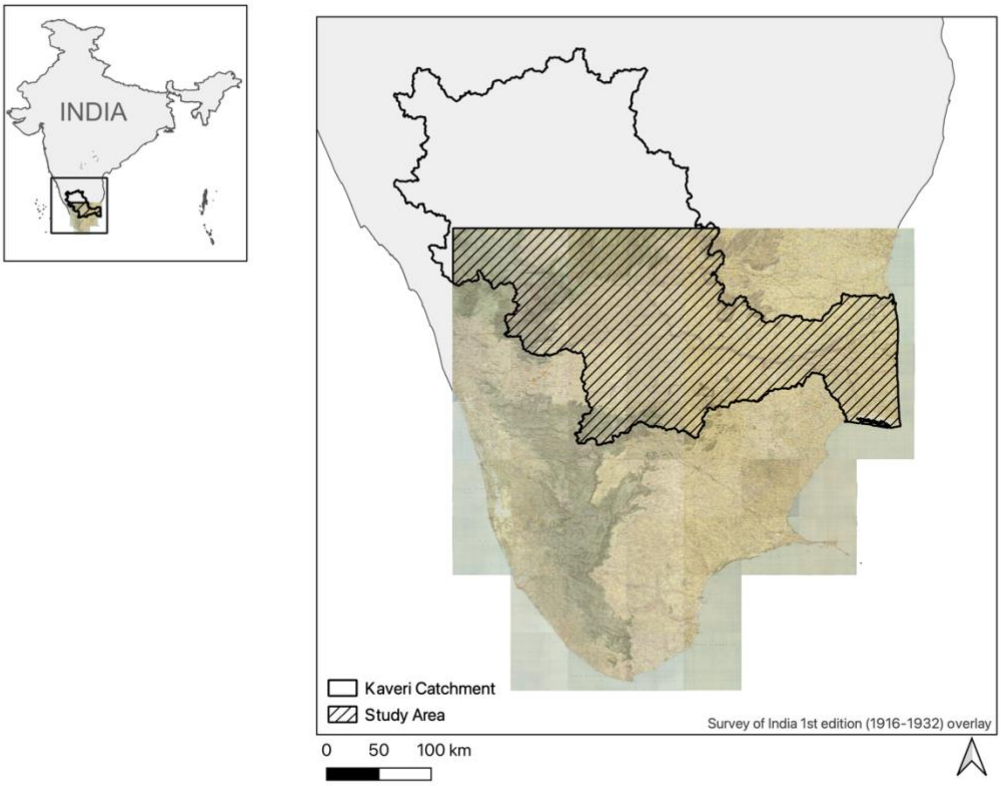

Figure 1 Study area within the Kaveri River catchment (shown in black), restricted by the extent of digitised historic maps.

To investigate how many of these digitised tank features still held water, satellite imagery from Sentinal-2 was used alongside a calculation of the water indices using a Modified Normalised Difference Water Index (MNDWI; Du et al. 2016). MNDWI was chosen instead of the standard NDWI because of its ability to enhance water bodies and suppress built-up features more efficiently. The imagery was analysed over an average of the period of 1st June 2022 – 31st March 2023, including both the NE and SW monsoons to maximise the likelihood of finding water in the tank features. The MNDWI was used to calculate an indicator for wetness over this period to establish which tanks still contained water.

However, there were some inconsistencies in the overlay of the tank features to satellite imagery (**Figure 2**), with tanks offset by up to 300m between the two datasets. This was rectified by creating a 300m buffer around each tank geometry and counting the number of cells intersecting the buffer where MNDWI > 0 was found. This number was then divided by the total number of cells intersecting the tank geometry, with the value capped at 1 (e.g., if the tank had expanded). This process was undertaken in Python 3.10 and is summarised in **Equation 1**.

$$P_{wet} = \frac{|B_{wet}|}{|G|} , \in [0,1] \tag{1}$$

Where: P_{wet} is the proportion of the historical tank area that is currently occupied by water; B_{wet} is the set of raster cells that intersect the buffer where MNWI > 0 and G is the set of raster cells that intersect the historical tank geometry.

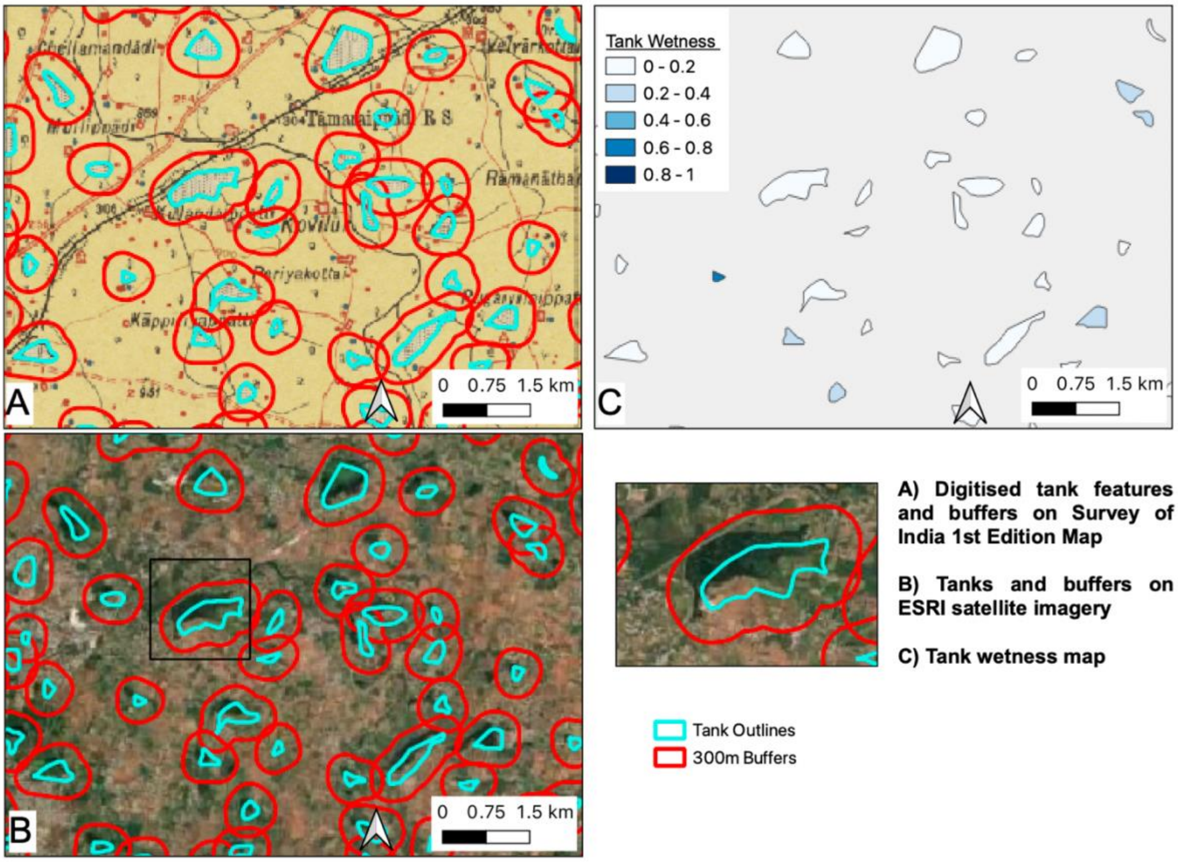

Figure 2 Buffered tanks, demonstration of offset on satellite imagery and tank wetness values (as per **Equation 1**)

To examine spatial patterns in the wetness of the tanks, a Global Moran's I and Local Indicators of Spatial Association (LISA – Local Moran's I) analysis of the tank wetness values (**Equation 1**) was conducted using the PySAL library for Python 3.10. A row-standardised distance band weights matrix was used, with the threshold set to 30,514 m (the smallest value that ensures all tanks have at least one neighbour). Pseudo-*p* values were calculated using a standard simulation approach with 9999 permutations and the significance threshold set to 0.05.

3. Results

The results of the LISA analysis, given in **Figure 3,** shows statistically significant clusters and outliers of wet and dry tanks. There is a very clear geographical pattern to tank wetness, with large clusters of dry tanks to the east of the catchment, towards the delta, and large clusters of wet tanks to the north and west with a small cluster on the east coast.

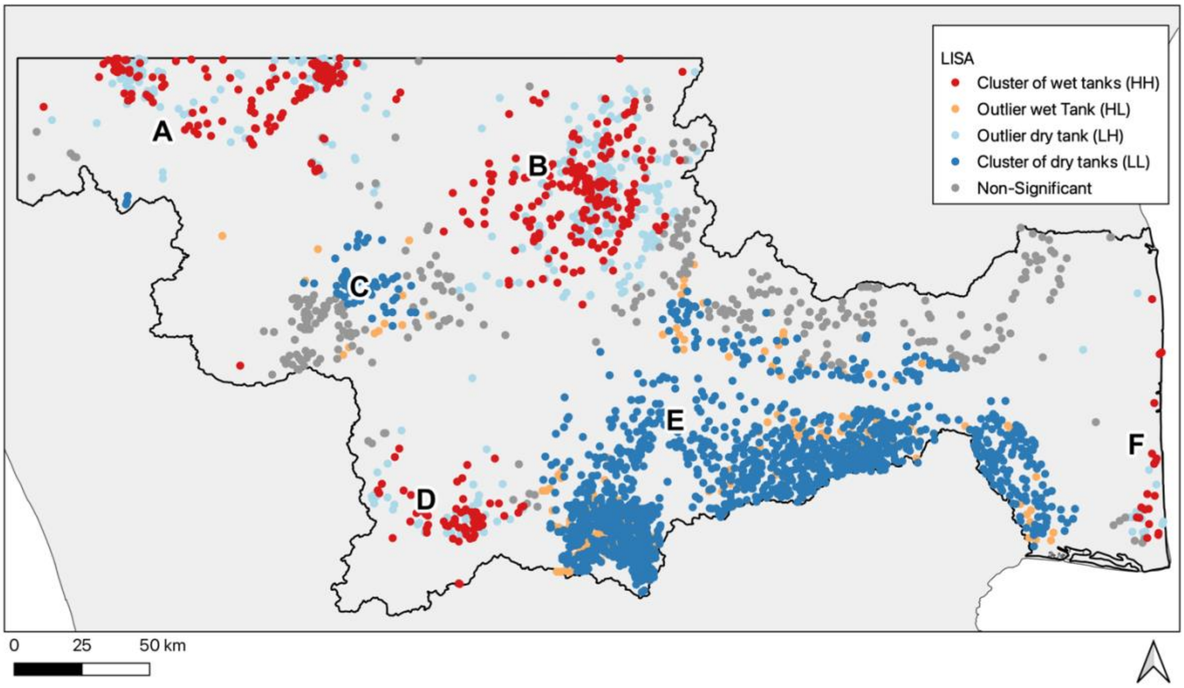

Figure 3 Results of the LISA Clustering based on estimated tank wetness.

4. Discussion

Some of the clusters of wet tanks **(Figure 3**) indicate areas of successful tank rehabilitation projects. For example, cluster B is a tank rehabilitation scheme led by the Water Resources Department (WRD), which diverted surplus water from the Mettur Dam (**Figure 4**) into 79 restored tanks (WRD 2023), demonstrating how tank rehabilitation can help to ease water scarcity. In other cases (clusters A, D) where there is no evidence of formal tank rehabilitation projects, further investigation would be required to determine whether these wet tanks are used as a water supply. However, even if not, there are several benefits to allowing defunct tanks to fill, including enhancing groundwater recharge, improving the supply of nearby wells, and increased biodiversity (Palansami et al. 2010). Cluster F, on further inspection of satellite imagery, consists of a mixture of shrimp farms, salt works, with tanks further north.

Figure 3 also provides a clear picture of which regions within the Kaveri River catchment have predominantly dry tanks, and thus could benefit from a focused programme of tank rehabilitation. The largest cluster of dry tanks (E) is downstream of several major dams (**Figure 4)**. The reason for the decline of tank usage in this area is provided by the co-presence of canals, which date back to British Colonialism. This region was heavily developed during this period, including the creation of the Mettur Dam 1934. This development included the extension of existing canal systems, to provide agricultural irrigation to over 300,000 acres of new farmland and extending the area of double-cropped lands by 70,000 acres (Cauvery Reservoir Project, IOR/L/E/367).

However, the canal infrastructure also allowed the British to charge for water from government-owned canals, leading to the disconnection of tanks, a collective resource that could not be governed in the same way (Parasarthi, 2017). Combined with the structural economic shifts of the colonial period, water insecurity subsequently became a significant challenge in this downstream region. Irrigation tanks, whilst not the only answer to solving water scarcity, could ease the problem and provide a sustainable form of water management to complement existing sources.

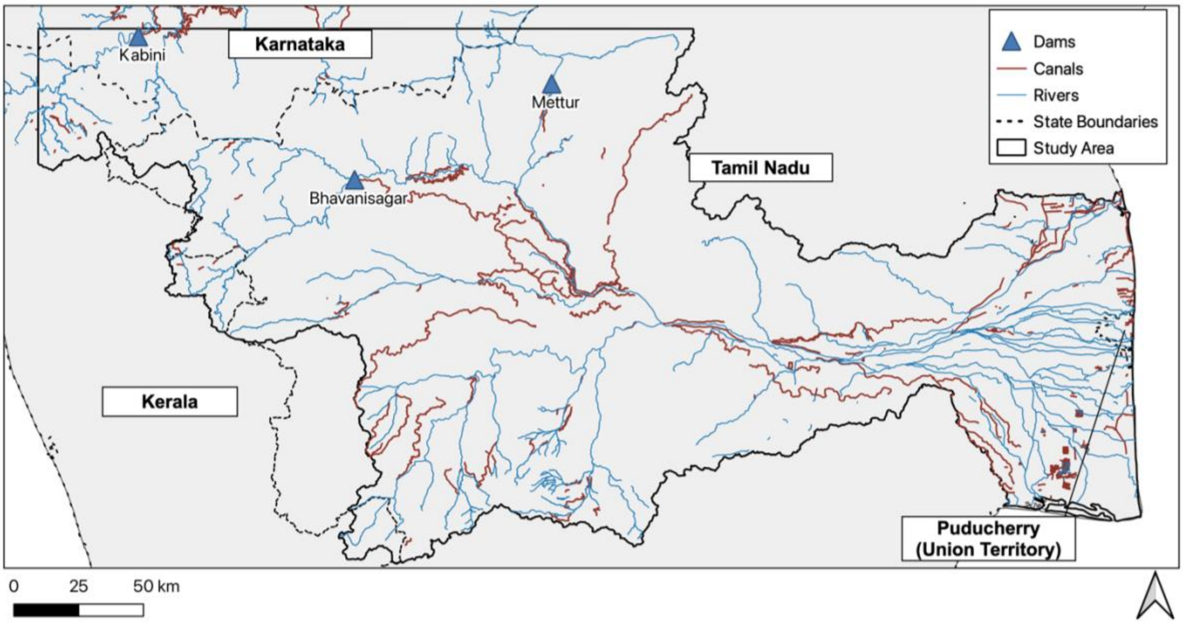

Figure 4 Dams and Canals of the Study Area

5. Conclusion

This research provides valuable insights into the complex history of the management and decline of irrigation tanks in the Kaveri catchment, South India. It highlights key regions of contemporary decline and rejuvenation, as well as evidence of the effect of historic irrigation policies on modern South India.

Reproducibility Statement

The data and Python Code associated with this project are available here.

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Archival Material

Collection 58/1 (Appendices) Irrigation - Cauvery Reservoir Project in Madras: Volume 1 (1910-1924) The British Library, India Office Records (IOR/L/E/367)

Biographies

Charlotte Evans is a PhD student in Geography at the University of Manchester. She is interested in interdisciplinary approaches to studying both the human and physical geographies of water and rivers. She is affiliated with the French Institute of Pondicherry, India.

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