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Original Article

A Study on Groundwater Resource Management and Fort-Based Water Systems under Chhatrapati Shivaji Maharaj with Emphasis on Indigenous Engineering and Sustainability

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Abstract

Traditional techniques of water collection have become vital to modern irrigation as well as for climate adaptation, especially in arid regions. This study explores the groundwater resource management and fort-based water systems of Chhatrapati Shivaji Maharaj's era. The construction of reservoirs, stepwells and subterranean water lines was an important aspect of his water conservation measures for the support of the Maratha Empire. Water tanks sometimes are located within the structure of the hill fort known as Sinhagad, near Pune. There are 48 of them altogether that can be seen in the fort. It was observed that there was a rain gauge structure near Kushavarta talao. Water was allocated based on an individual's status in the administration and in fixed quantities. Not only did they provide a steady water supply, but their introduction was also an enhancement of defensive features of the fortifications, which were previously based on outside sources. The water harvesting technologies built in these forts considered the geography as well as water sources available. If we a glimpse into our rich past, a lot of lessons can be learned of how our forefathers have dealt with the changing climatic conditions and water requirements and in this regard, they had developed water harvesting structures based on the peculiar geographical features of the region.

Keywords: *Groundwater Management, Fort-Based Water Systems, Indigenous Engineering, Sustainability, Rainwater Harvesting, Maratha Empire*

Introduction

The WPI estimate of Maharashtra is 0.47, indicating high water stress [1]. Joint and comprehensive approaches towards water management with an aim of desertification prevention and drought resistance enhancement [2]. However, the country's water security is under threat due to poor management. This problem is being worsened by climate change, owing to increased heat stress and irregular rainfall [3]. It is due to the geological property of the Deccan Plateau that has made them especially vulnerable to changes in rainfall patterns [4]. The region's aquifers seem to drain rapidly and replenish at a fairly rapid rate [5]. Traditional water collection practices have played an essential role in enhancing irrigation and adapting to climatic change, especially in arid regions [6]. His very careful design of reservoirs, stepwells and underground water canals contributed much to the survival of the Maratha empire [7]. Traditional water collection practices have played an essential role in enhancing irrigation and adapting to climatic change, especially in arid regions [6]. His very careful design of reservoirs, stepwells and underground water canals contributed much to the survival of the Maratha empire [7]. The major research questions raised in this study are: What were the key components of groundwater resources management under Chhatrapati Shivaji Maharaj? What impact did design ideas for water systems within forts have? What are the insights they can draw for water management today and what makes these systems viable? [7]. The geographic extent includes the important Maratha forts—Raigad, Sinhagad, Rajgad, Pratapgad, Panhala, Shivneri, Sindhudurg and Vijaydurg [7].

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The history period is the limited scope of the 17th century (corresponding with the period of Shivaji Maharaj, 1630 to 1680) [7] and the limitations recognized are not much archaeological evidence and reliance on secondary historical sources [7].

Historical Context and Water Management Needs

1. The Deccan Region: Geography and Climate

The high-lying hills of the Western Ghats along the western coast of India cast the orographic rain shadow on the Deccan Plateau [8]. The catchment area of the present study on watersheds of the Anantapur district is a rain shadow zone of the Western Ghats in the center of the Deccan Plateau, India. One of the land degradation-affected areas in the country with an average annual rainfall of about 560 mm [8] is vulnerable to drought. The Deccan Plateau is the semi-arid region, as a result of the rain shadow effect of the Western Ghats [9]. Marathas have contributed in many significant ways towards developing and maintaining rural water supply works. In the early days the Marathas, under the leadership of the king Shivaji, laid out high-elevation forts around the Western Ghats that capture rainwater in rock-cut cisterns and reservoirs [9].

2. Shivaji Maharaj's Vision for Water Security

While many know about the military tactics and methods of Shivaji Maharaj, his foresight and vision in storing and utilizing rainwater on forts is little-known [9]. Within his forts, elaborate rainwater-collecting mechanisms were built, which included stepwells, rock-cut reservoirs and underground water lines to minimize the problems of water scarcity. These developments provided a reliable source of water but also enhanced the fortifications' capacity to defend themselves, as they no longer had to rely on water supplies from outside the fort. Amatya says, "Then after finding out that there is water in the area, a fort should be built." If no water is available and water is necessary to hold the fort, reservoirs and tanks should be constructed, sufficient to last for the rainy season throughout the entire fort, by fracturing the rock. While excavating the tank, Shivaji would have had in his mind its three-fold benefits. As a first step, the supply of sufficient water could be achieved by digging a tank. Second, the enormous block of stones from the quarry built for the tank might be utilized for constructions. Third, the rock could be used to dig the scarp so that the defense of the citadel could be ensured for Bālekilla.

3. Administrative Framework

Adnyapatra was a book written in Modi script about ideas on Maratha policy, administration and statecraft by Ramchandra Pant Amatya to give instructions to kings for maintaining sovereignty through fortification [9]. Very high importance is given to the forts. The forts are characterized as the essence of the entire state [9]. Obviously, the crucial element of a fort was drinking water [9]. During the period of Shivaji, the system of water supply remained unchanged on all forts. A fixed volume of water was allocated to each of the individuals based on their status in the government and this was to be carried physically from storage tanks/lakes to the individuals by the persons designated to carry water. Amatya also advised in not being dependent on a water source (don't be dependent on one tank). For, during conflict, springs become dried up due to the roar of firearms [9]. Each fort had enough water and cornland to be self-supporting and, in case of siege, each fort could maintain a small garrison for any length of time [9].

Indigenous Engineering: Types Of Water Systems

1. Rock-Cut Cisterns

The hill fort of Sinhagad near Pune has various water tanks placed inside its framework. These are actually man-made cisterns that are carved into the rocks and collect and store rainfall (also known as tanks). The creation of these tanks was a by-product of the digging out of boulders used for the construction of the forts. A total of 48 such takes can be observed at the fort [10]. These tanks retained water for four to six months after the rainy season [10]. Some cisterns [10] like Dev, taken in Sinhagad Fort, were blasted at a greater depth to provide groundwater as springs in the cistern at the lower level and excavated at the upper level of the ground. Since this water accumulated in basalt rocks, it automatically became filtered and gained shield from percolation and seepage [11].

2. Artificial Lakes and Reservoirs

The artificial lakes are created where the water streams pouring down the sides of the fort opposite one another meet on the lower-level ground of the fort area [10]. One of the largest and most important forts of Shivaji is Raigad Fort, where some of the best instances of such all-weather lakes are found. Among them, twelve of them are noteworthy for both manufactured and natural ones [10]. Gangasagar Lake is an artificial lake in the vicinity of Raigad Fort [12]. Rocks from this site were duly dug and chopped and were used to construct the various components of the fort; thus, Gangasagar Lake was formed [12]. It is suggested that these lakes are formed on waterproof soil and rock where there is not a great amount of percolation of the water [10]. The natural lakes are prevalent in the foothills, where they get a continuous water supply from the surface and subsurface. In addition, these lakes are also supplied by natural springs [10].

3. Stepwells (Baoli/Bavadi)

At the Panhala Fort is the "Hidden Well" [13] called Andhar Bavadi. This three-story building was constructed to hide the main water source to the fort from enemies and to prevent them from poisoning the water [13]. Le fort est doté d'Andhar Bavadi, un réseau d'adductions d'eau souterraine, qui permet de camoufler les sources d'eau en cas de long siège du fort [14]. No. 15 andhar Bavadi (a hidden stepwell), is one of the features of interest. Indoors, you can see some old buildings like 'teen darwaza,' 'sajja kothi,' and 'andhar bavadi' [2]. Explore Andhar Bavadi, a secret three-story stepwell to avoid water poisoning caused by adversaries [2].

4. Underground Water Channels and Springs

Fort has two water springs (called Ganga-Jamumna), which have water all year round [3]. There are

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two springs known as Ganga and Yamuna, which spring within the walls and flow throughout the year. This natural supply was invaluable for the defense and was of immense assistance to the inhabitants in facing long sieges [3]. Until now, the springs of the Ganga-Jamuna flow, a sign of the fort's self-sustaining architecture [15]. His water management, especially with installing reservoirs, stepwells and underground water canals, helped much in nurturing the Maratha Empire [12]. Surrounded by the sea, the fort still has several freshwater wells, a feat of medieval architecture that allowed inhabitants to have clean water at any time [5].

5. Rainwater Harvesting Infrastructure

An old rainwater collection system, including an old rain gauge on top of the fort at Raigad [4], has been discovered by conservationists. The rain gauge structure was seen near the talao (Kushavarta) [4]. Its complex comprised a palace, a court, a treasury and a water supply station consisting of a system of water tanks, which would collect rainwater, ensuring a water supply for the garrison [4]. The topography of these forts, as well as the water resources available, was taken into consideration in developing the water harvesting technologies. The excavated portion was blasted in the ground and made fissures to bring some water in the form of a spring in the cistern [10].

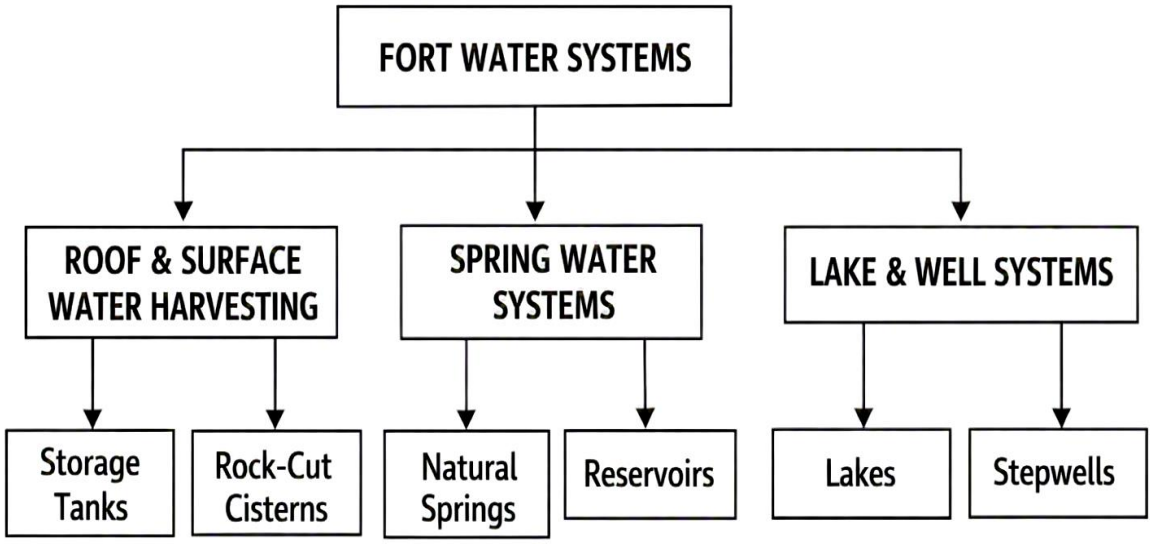


Figure 1: Typology Of Fort-Based Water Systems Under Chhatrapati Shivaji Maharaj [9,10]

Table 1: Comparative Analysis of Water Systems Across Major Maratha Forts [7]

Fort Name	Type	Water Structures	Key Features	Current Status
Raigad	Hill Fort	84 tanks, Gangasagar Lake, rain gauge	1,300 acres; capital fort; watertight basalt rock	Under RDA conservation
Sinhagad	Hill Fort	48 rock-cut cisterns (*take*)	*Dev Take* with perennial water	Functional; tourist attraction
Rajgad	Hill Fort	Multiple lakes and reservoirs	First Maratha capital	Partial ruins
Shivneri	Hill Fort	Ganga-Jamuna springs, Badami Talav	Birthplace of Shivaji Maharaj	Functional
Panhala	Hill Fort	Andhar Bavadi (3-storey), multiple baolis	Concealed water source	Functional
Sindhudurg	Sea Fort	Freshwater wells	Surrounded by seawater	Functional
Kolaba	Sea Fort	Freshwater wells	Seaside fort	Functional

Groundwater Resource Management Strategies and Sustainability Analysis

His policy of judiciously utilizing reservoirs, stepwells and underground water canals helped in the preservation of water and hence played an important role in sustaining the Maratha Empire [12]. The water was stored in these tanks for a duration of four to six months after the rainy season by intentionally placing the reservoirs in strategic locations and employing the natural water filtering properties of basalt rocks [11] as well as a minimal seepage rate [10]. I) Higher depth of the excavation area on the ground was blasted, making fissures underground for attaining groundwater in the form of springs [10]. A certain amount of water would be distributed from the tanks/lakes to the people by water carriers based on their administration hierarchy [9]. Should not rely solely on one tank. For, during conflict, springs become dried up due to the roar of firearms [9]. Historical water harvesting practices… are also found to be essential for water for irrigation and coping with the present climatic conditions,

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especially in the dry lands [6]. By utilizing the natural contours [11] to obtain ecological sustainability by working with nature [16] and minimum environmental impact [16]. Social sustainability was secured through a fair distribution scheme [9] and through decentralized approaches to water management [9]. Lessons were learned about the sustainability of engineering construction materials through reliability and continuity [16] and redundancy with multiple water supplies [9]. The Raigad Development Authority has formulated a scheme for conservation and development of Raigad Fort with an allocated budget of Rs 606 crore [4] and for decentralized rainwater harvesting (RWH) in water-starved areas [6] and for SDG 6, Clean Water and Sanitation [1], the systems are relevant to the present times.

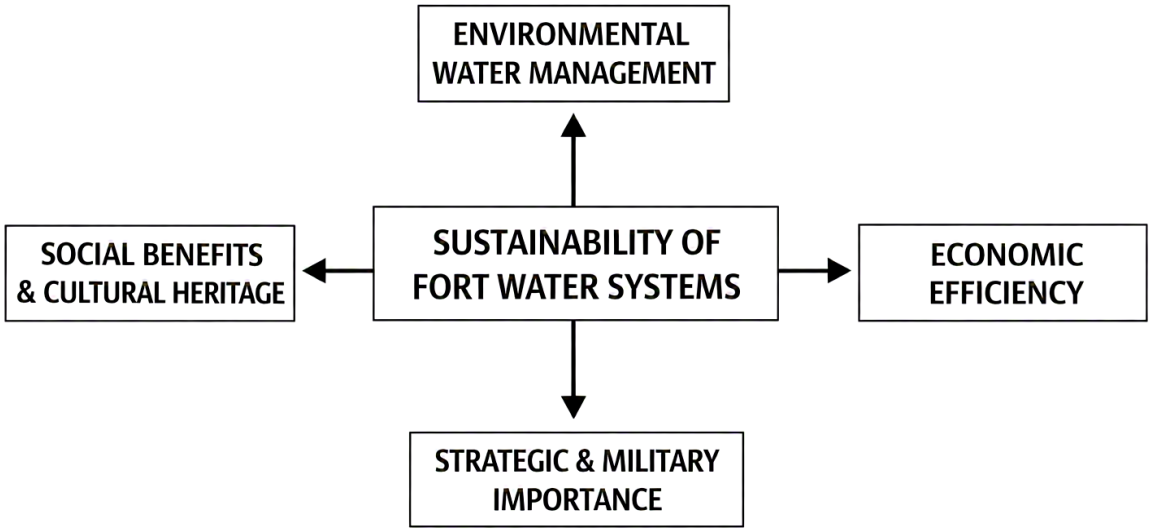


Figure 2: Sustainability Dimensions of Shivaji Maharaj's Fort Water Systems [7,8]

Case Studies and Lessons for Modern Water Management

Since 1909 [8], Raigad Fort has been the central tube under the Archaeological Survey of India (ASI). The fort, with an area of ~1300 acres, had about 84 small and big water tanks and reservoirs [7]. The fort used natural slopes and gradients to catch and hold rainwater for use [7]. In the fort, all tanks have been built based on a slope study that ensures that each tank can have water [7]. In 2017, there was an mou between ASI and Raigad Development Authority (RDA) [8]. There are a few water tanks within the framework of the hill fort at Sinhagad near Pune. These are really rock-cut cisterns called takes or tanks that collect and store rainwater. In total there are 48 such takes in the fort [9]. Some cisterns have been developed, like Dev's, in the Sinhagad fort [9]. The famed Deotake on Sinhagad would be a role model, as it has continuously satisfied the thirst of visitors and even of villages around for centuries [10]. The fort is surrounded by seawater, but there are several wells for fresh water, a wonderful feat of medieval architecture to provide a constant supply of potable water to the inhabitants of the fort [11]. After all, this fort has freshwater wells on its grounds, even though it is a seashore fort [12]. These water harvesting technologies of the forts have been built after considering geography and available water sources on the forts [13]. The precinct government will sanctioned a budget of Rs 2.25 crores to recreate rock-cut tanks around the project [10]. An examination of our historical legacy would give us many lessons in adaptation to the varying climatic conditions and water requirements by adopting water harvesting systems according to the unique topography of the region [13].

Conclusion and Future Research Directions

Through a glimpse of our rich past, we will learn a lot of lessons as to how our forefathers managed to adapt to the changing climatic patterns and re-appropriated water in accordance with the unique topography of the region.

It has reveals that ancient water collection systems have had a significant role in irrigation and in adapting to climatic conditions, especially in desert regions. The analysis clearly indicates that the water systems developed by Shivaji Maharaj are an integrated system in that demonstration. From the judicious location of reservoirs, stepwells and subterranean water lines, Shivaji Maharaj ensured fort self-sufficiency. There are excellent examples demonstrating knowledge of local geology and hydrology around the rock-cut cisterns, or "takes," and the artificial lakes. These tanks retained water for four to six months after the rainy season. Each person got a certain amount of water, based on his rank in the administration. The systems demonstrate ecological, social and engineering sustainability design ideas. The Raigad Development Authority has come up with a Rs 606-cr plan for the protection and enhancement of the Raigad Fort. Future research should focus on broad samples of sites that have received less archaeological write-up than other forts, the ability of water storage systems to be quantified and comparison studies with other medieval water systems and development of practical models of contemporary adaptation.

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Conflicts of interest
The authors declare that there are no conflicts of interest regarding the publication of this paper.

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