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Ecohydrological perspectives of declining water sources and quality in traditional water bodies of Delhi

R.B. SINGH[1], S. GAHLOT[1] & ANJU SINGH[2]

1 Department of Geography, Delhi School of Economics, University of Delhi, Delhi-110007, India
rbsgeo@hotmail.com, rbsgeo2@gmail.com

2 Department of Geography, Aditi College (University of Delhi), Delhi Auchandi Road, Bawana, Delhi-110039, India

Abstract This paper investigates the spatio-temporal changes in the traditional water bodies of Delhi along with the processes and forces behind the water quality change, and the ecohydrological consequences of the changing status of traditional water bodies. In 1970, the total number of water bodies was 807 with an area of 14.41 km^2, which declined by 21% to 640, having an area of 8.51 km^2 in 2008. About 108 (23%) dry water bodies have disappeared and this contributes to loss of 4.47 km^2, i.e. 60% of the area under the dry water bodies. The study shows that there is not only decline in the total number of water bodies but there is deterioration in the quality of water bodies. Among 27 wet water bodies, only 11 have clean water, the remaining 16 were filled with dirty water and filth due to inflow of wastewater from the nearby residential area and dumping of garbage around them. The land use in the catchment areas influences water quality through inflow of nutrients, organic and inorganic contaminants and siltation. The study reveals that extinction of traditional water bodies and dying tradition of construction and management of these water bodies has resulted in the serious decline in the level of groundwater in Delhi. The area of brackish water (EC > 2000 μs/cm) increased by 70% from 1977 to 2000. Birds like coots which prefer clean water have also started dwindling with the loss of habitat. The Indian purple moorhen has become uncommon in recent times and the number of frogs has declined in Delhi. The Delhi Government has prepared a Nine Point guideline for the revival of water bodies of Delhi.

Key words ecohydrology; water quality; traditional water bodies; biodiversity; Delhi, India

INTRODUCTION

Different types of traditional water bodies are found in India and were designed to suit the local needs of the people. As in the northern plains and arid part of western India, Delhi also has structures such as *kundi*, *baoli*, *hauz* stepwells, bunds, ponds (*johad*), etc. and in southern India there are tanks and artificial lakes (Barah, 1996). The natural topography was utilized to create tanks and reservoirs and other water harvesting structures. All these form part of a complex traditional water management system transmitted by one generation to another generation, and these water bodies were maintained and preserved by the local communities through innovative ideas and active participation of the people (Narain, 2006). Community members jointly maintained these facilities, conserving and protecting the catchments, protecting the water bodies from pollution and ensuring the equitable and fair distribution of water. The community, which was supposed to be the preserver of this traditional water wisdom, became the destroyer of this glorious tradition of water management in the present context. The present study is designed to investigate the driving forces responsible for change in the traditional water bodies of Delhi, together with the ecohydrological implications.

THE STUDY REGION AND RESEARCH METHODOLOGY

The climate of Delhi is of semi-arid type, with an average annual rainfall of around 611 mm. Most of the precipitation (over 80%) occurs during the southwest monsoon between June and September. Delhi had a population of 16.75 million in 2011, and now faces acute shortages of water and the problem is aggravated during the summer months. The landscape of Delhi was dotted with several water bodies that formed its life line (Gupta, 1987). Delhi is divided into several administrative units, out of which samples for study were selected from the North West, South West, East and South, based on their rural and urban character. A purposive sampling method was used for the selection of the five villages from each sample district making a total of 25 villages. A village is a rural settlement having population less than 5000 and a population density less than 450 persons/km^2. The village population is mainly engaged in primary activities.

To assess the spatio-temporal change in the water bodies, data has been generated through digitization from toposheets of two time period, 1970 and 2008.

HISTORICAL AND CULTURAL BACKGROUND

Several water bodies were constructed by the rulers of Delhi in the past. These are known as *baolies* and *hauz*. In the historic city of Delhi, these water bodies were an integral part of the planning and development of the settlement and forts. The city of Delhi was laid out on and around the rocky terrain of Aravali for safety purposes. The rugged hilly terrain of Aravali offered no scope for building a canal from the Yamuna River. The only option left was to harvest the rain water by trapping the stormwater generated from the ridge. Besides tanks (*hauz*), the sultans and their nobles built and maintained many *baolies*. In fact, Delhi was the land of *baolies*, both big and small, and scattered over various parts mainly on the rocky terrain (Delhi Administration, 1987; Hassan, 1997).

While the city depended upon *hauz* and *boalies*, the rural area ensured the availability of water through their earthen ponds. The villages of Delhi had traditional systems of various separate and interconnected earthen ponds popularly called *johads*; they vary in shape, size and depth. Their size remained almost small (generally one hectare or less) for the purpose of easy maintenance and their average depth is about six metres. *Johads* were carved out from natural depressions or by deliberately excavating the surface. *Johads* were de-silted annually with active participation of the community in order to maintain the water retention capacity of the *johads* and at the same time keep flooding under control. One of the major roles of *johads* in the villages was to recharge the wells located in their vicinity, and thus sweet potable water was available to the villagers year round. *Johads* also facilitated soil conservation, improvement of the moisture content of the soil, and nourished various flora and fauna (INTACH, 1998) (Fig. 1).

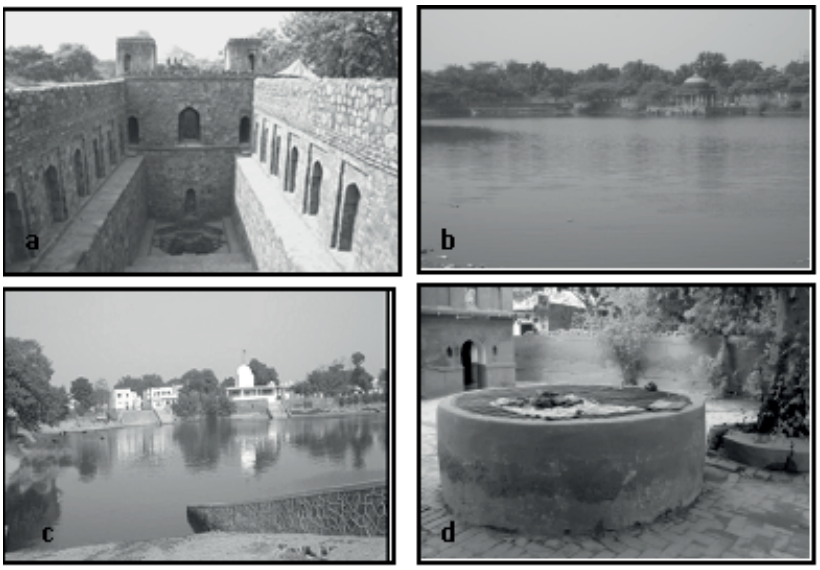

Fig. 1 (a) Wazirpur baoli; (b) Hauz-e-Shamshi; (c) *johad* in rural Delhi, and (d) an abandoned well.

STATUS OF TRADITIONAL WATER BODIES

At present 640 water bodies officially exist in Delhi under the jurisdiction of various government agencies. The South West district has the maximum number (206) of water bodies under the revenue department (Table 1). The study shows that every settlement has more than one traditional water body as old as the settlement. These water bodies are both natural and man made. The village water bodies, i.e. *johads*, are located outside the village and *abadi* mainly at the outer corner of the village in the lower parts so that rainwater can easily accumulate in them. *Johads* are located on

pasture lands and in the fields. After the construction of a water body there was a customary planting of native tree species like *peepal*, *neem*, *bargad*, etc., worshiped by the community as a sacred grove.

Table 1 Spatial distribution of water bodies of Delhi, 2008.

District	Number of water bodies			Area of water bodies (km^2)			% total water bodies	
	Dry*	Wet*	Total	Dry	Wet	Total	Dry	Wet
North West	82	151	233	0.69	3.67	4.36	35	65
North	1	27	28	0.015	0.54	0.55	4	96
North East	3	7	10	0.12	0.16	0.28	30	70
East	2	11	13	0.12	0.31	0.43	15	85
New Delhi	0	5	5	0	0.035	0.035	0	100
Central	0	3	3	0	0.035	0.03	0	100
West	39	14	53	0.26	0.09	0.35	74	26
South West	169	45	214	1.28	0.3	1.58	79	21
South	59	22	81	0.51	0.38	0.89	73	27
Total	355	285	640	2.99	5.52	8.5	55.4	44.5

Source: Survey of India Toposheets, 2008

* A dry water body does not contain water at present. It is used as grazing, playgrounds, etc. Earlier, such water bodies were used by the community for various uses. A wet water body contains water round the year and its water is used by the community for various purposes.

DECLINING TRADITIONAL WATER BODIES

The study reveals that the traditional water bodies of Delhi have declined over space and time in terms of both quantity and quality (Agrawal & Narain, 1997). In 1970, the total number of water bodies was 807, which had declined to 640 by 2008, i.e. an absolute decline of 167 water bodies. There is a loss of 21% of the total water bodies and the area under water bodies declined from 14.41 to 8.51 km^2, a total loss of 5.9 km^2 (Fig. 2). This amount contributes to a loss of 41% of the area under water bodies. A greater number of dry water bodies no longer exist; 108 (23%) dry water bodies have disappeared and this contributes to loss of 4.47 km^2 (60%) area under the dry water bodies. The study also reveals that a dry water body is more vulnerable to extinction as it is easier to encroach. The maximum decline has been witnessed in the total number of dry water bodies. As per the analysis drawn from the primary survey, it is found that during 1960–1970 there were 87 water bodies in total in the 20 sample survey villages. In 2009, they had reduced to 54. Out of these 54 water bodies, 27 are wet and 27 are dry. During the time period between 1970 and 2009, 33 water bodies ceased to exist due to various reasons.

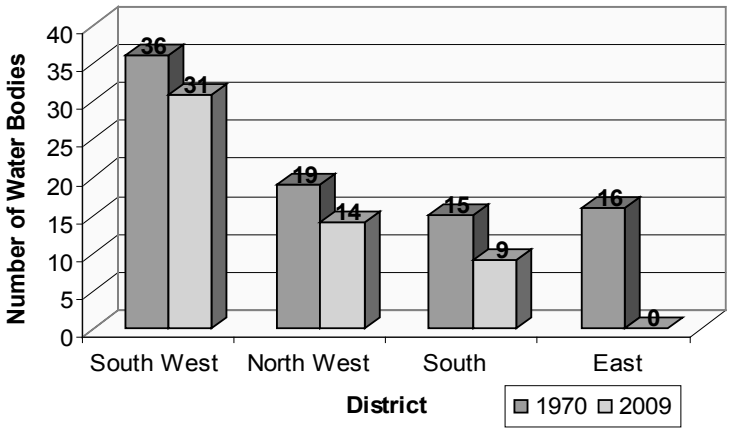

Fig. 2 Variations in the number of water bodies in the sample districts, 1970–2009. Source: Primary Survey, 2009.

WATER QUALITY STATUS IN TRADITIONAL WATER BODIES

Among 27 wet water bodies, only 11 water bodies have clean water; the rest were filled with dirty water and filth due to inflow of wastewater from the nearby residential area and dumping of garbage. The existing/surviving water bodies at present have no problem like sewage disposal, wet with clean water and encroachment. The study shows that out of 54 surveyed water bodies, only 11 (20%) were found as surviving water bodies (Table 2). Previously, these water bodies were used for domestic purposes, including drinking. However, they are no longer in use for drinking purposes, and are only used for washing, bathing and water requirements of livestock. In peripheral areas, they are also used for irrigation.

Table 2 Water quality status of the sample ponds from the sample villages.

Villages	Location of pond	pH	TSS (mg\L)	DO (mg\L)	COD (mg\L)	BOD (mg\L)	Ammonia (mg NH^{4+}/L)	Aquatic life*	Algae
Rajokari	Residential	8.3	34	12.5	44	7	5.1	No	Yes
Jharoda Kalan	Field	8.8	88	7.8	124	17	0.03	No	Yes
Jharoda Kalan	Field	8.0	10	6.6	44	7	2.8	Yes	No
Ghumanhera	Residential	8.8	158	8.1	76	14	3.3	No	Yes
Ghumanhera	Road	8.5	66	8.0	12	2.0	0.4	Yes	Yes
Ghumanhera	Field	8.6	130	7.6	36	5.0	0.5	Yes	No

* All forms of aquatic life including fish. Source: Delhi Pollution Control Committee, 2009.

The land use in the catchment area influences water quality through inflow of nutrients, organic and inorganic contaminants and siltation. Therefore, the location of water bodies has profound bearing on its water quality. Aquatic life is found in the ponds located in and around the fields. The overall analysis of water bodies based on their physical condition reveals that 59% in the sample villages are threatened due to encroachment, pollution and eutrophication. Encroachment and pollution are the major threat to the survival of traditional water bodies of Delhi. Out of 285 wet water bodies, 120 contain dirty water and 165 contain clean water. The South West and North West districts have the most clean water bodies, 89 and 55, respectively (Central Pollution Control Board, 2001) (Fig. 3).

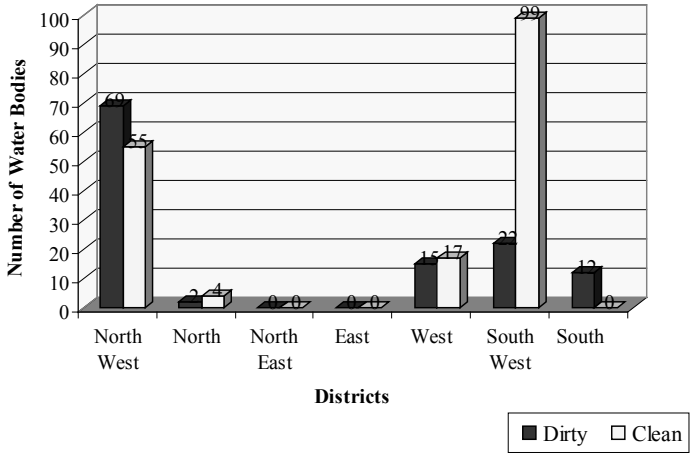

Fig. 3 Distribution of dirty and clean water bodies under the Revenue Department. Source: Revenue Department, 2008.

ECOHYDROLOGICAL IMPACTS ON TRADITIONAL WATER BODIES

The process of depletion started with the increase of population and destruction of catchments due to construction activities in and around the water bodies (Joshi, 2002; Singh & Singh, 2011). The increasing population of Delhi, from 0.4 million in 1901 to 16.75 million in 2011, and increasing

urbanization led to shrinkage of villages and agricultural land within Delhi. During 1961, rural Delhi occupied 1157.5 km^2, i.e. 78% of the total area of Delhi, and had 300 villages; gradually, with increasing urbanization, the percentage share of rural Delhi reduced to 38% in 2001 with 165 villages. The physical shrinking of rural Delhi has reduced the once vast stretch of agricultural land which acted as the catchment area for the water bodies. During the last four decades, land-use change due to rapid urbanization has resulted in the increase in paved area and decrease in the agricultural land which used to act as local catchment and a percolation zone (Athavale, 2003). Field survey shows that a number of water bodies in the East and South district were lost to meet the residential requirement (Table 3).

Table 3 Conversion of water bodies for different uses.

District	Farm house	Community hall	Residential area	Godown	Park	Playing field	Others	Total
South West	-	1	2	-	-	-	2	5
North West	-	2		2	1	-	-	5
South	1	-	4	-	1	-	-	6
East	-	-	13	-		2	1	16
Total	1	3	19	2	2	2	3	32

Source: Primary Survey, 2009.

Apart from ignorance from the community, government apathy towards these traditional water bodies has been a major factor behind decline of these systems (Narain, 2006). There are no clear laws to protect the traditional water bodies and their catchments. Planning responsibilities are only limited to providing drinking water to the citizens, providing housing and infrastructure facilities; protection, conservation and augmentation of the role of traditional water bodies for water supply has been totally ignored (INTACH, 1998; Rohilla, 2004). The introduction of piped water supply from far off sources and extraction of groundwater through tubewells has changed the human interaction and dependence on traditional water bodies.

Impact on biodiversity

These traditional water bodies not only provided water to the community but they have performed various ecological functions, including influences on microclimate. They have maintained the microclimate and have helped in minimizing floods. They have played a pivotal role in recharging the aquifers and thus maintained the groundwater level, controlled groundwater salinity and supported various flora and fauna. The organisms may range from small bacteria to big creatures like water snakes, beetles, water bugs, frogs, tadpoles and turtles. These water bodies have been rearing, breeding and nesting grounds for various resident and migratory water birds. The disappearance and degradation of these water bodies is a threat to the survival of biodiversity which directly and indirectly depends upon these water bodies for their survival. Due to loss of habitat, migratory birds such as the European kestrel, coot, etc. visited Delhi in smaller numbers during the winter of 2009. The Indian Purple Moorhen has become uncommon in recent times and the number of frogs has declined in Delhi (Ahmed & Tiwana, 2005).

Impact on groundwater

The study reveals that extinction of traditional water bodies and the dying tradition of construction and management of these water bodies have contributed to the serious decline in the level of groundwater in Delhi. Due to indiscriminate withdrawal of groundwater coupled with vanishing traditional water bodies which acted as recharge zones, the groundwater level of Delhi is declining by about 2 m every year. During the period of 40 years from 1960 to 2000, every part of Delhi experienced decline of the groundwater level. The maximum decline was experienced in South Delhi, 12–30 m, followed by South West district. The Yamuna River flood plain, North West, North, North East and East districts experienced a decline of 0–4 m (Fig. 4).

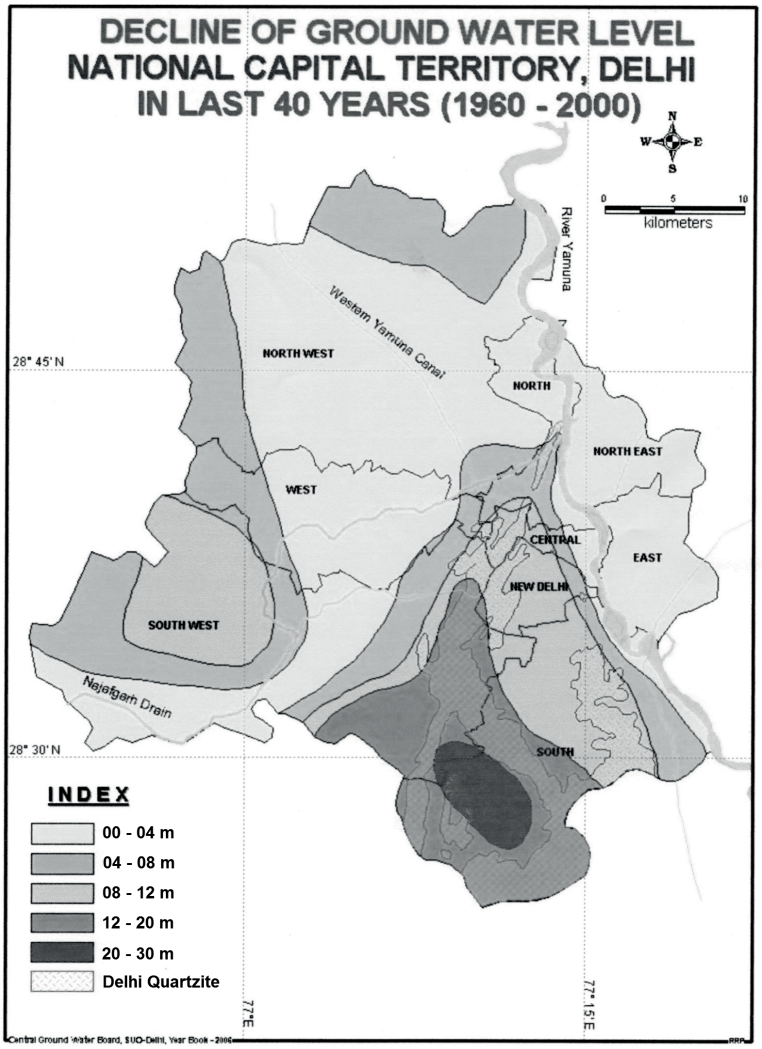

Fig. 4 Spatio-temporal variations in the groundwater of Delhi, 1960–2000. Source: CGWB, 2006.

Groundwater data for 1999–2008 shows that 264 km^2 of Delhi, mostly covering the South and South-West districts, experienced more than 10 m cumulative decline with a rate of 1.15 m/year. In the South, South West, West and New Delhi and East districts, 354 km^2 show declines of 4–10 m, a rate of 0.60 m/year. In the South district, 22 km^2 has been subject to a decline of 20 m at a rate of more than 2 m/year. The Central Ground Water Board (CGWB) has declared only the Central and North district "safe" for groundwater development, and all the other seven districts are placed under the category of "over exploited".

Impact of construction activities during the Commonwealth games

In October 2010, Delhi hosted the Commonwealth Games. The 47.3 ha site of the Games village was located on the flood plain zone of the River Yamuna. It is the flood plain that acts as a buffer and prevents flooding in populated areas. Construction reduced the groundwater level, worsening Delhi's drinking water crisis. Construction on the Yamuna River flood plain will cause ecological damage by hampering the process of groundwater recharge. In addition, due to construction of a flyover in south Delhi, an 800-year old traditional water body, "*neela hauz*" was adversely affected; nearly 60% of the lake was filled with concrete. This water body is critical to maintain water levels in South Delhi.

GOVERNMENT POLICIES AND TRADITIONAL WATER BODIES

The analysis of National Water Policies shows that not much emphasis is given to the protection and conservation of these traditional water bodies. Although environmental protection acts prohibits any kind of polluting activities around the water bodies, there is still no policy to protect these traditional water bodies and no strict law against encroachment (Banerjee & Bhatnagar, 2001). In the 1962 and 2001 Master Plans for Delhi there is very little mention of the traditional water bodies and their roles are recognized for recreational purposes only. Town planners and architects have failed to see the value of traditional water bodies in the city and over the years have allowed these water bodies to be decimated. Planners only see land for buildings, not land for water bodies. The declining levels of groundwater in capital have become a matter for concern. Therefore in MPD-2021 planners recognized the value of traditional water bodies in recharging the aquifers, and hence in MPD-2021 serious concern is expressed about the protection and preservation of traditional water bodies of Delhi (DDA, 2007). The Delhi Government has prepared Nine Point Guidelines for the revival of water bodies of Delhi. The revived water bodies are deepened, desilted and a boundary wall, inlets and concrete walk way have been constructed around the water bodies (Bhatnagar & Mukherjee, 2006). Plantation work around the water bodies has been assigned to the Forest Department. Lack of an integrated, holistic and ecosystem approach in the whole planning and implementation process has been a major limitation of the plans and policies regarding traditional water bodies. These water bodies are unique ecosystems and hence it is imperative to undertake an integrated and holistic approach based on the ecosystem requirements. Not even the best policies and technologies can solve the problem of depletion and degradation of traditional water bodies, unless people's attitudes, perceptions and habits change. There should be awareness programmes to sensitize the public and youth about the value of these water bodies and the consequences and losses due to their abuse.

CONCLUSION

The traditional water bodies of Delhi have declined in quantity and they are degrading in quality and anthropogenic activities have profound bearing on the well being of the water bodies. For the sustainable development of this traditional system it is suggested that all water bodies should came into the jurisdiction of a single authority – Integrated Water Bodies Protection and Management Authority. Mapping and creation of database of water bodies should be done with the help of local people and remote sensing and GIS. Catchment area should be preserved and there should be ban on unauthorized construction in the pasture and farm lands in the fringe. Encroachment, pollution and catchment destruction has been found the most threatened factors for the survival of traditional water bodies. There should be regular monitoring of the water bodies and catch the disease in its early stage and cure it. Efforts should be done to strengthen the belief that conservation and management of traditional water bodies are still capable to manage their water problem. Water bodies owning departments should tie up with various citizens' organizations and Residents Welfare Associations (RWA) to maintain the traditional water bodies, their catchment and storm water drains under the *Bhagidari* (Partnership) scheme of Delhi government. It is time to acknowledge and value every drop of water and rejuvenate our "dying wisdom" and tap the traditional system which ensured adequate availability of water for all, which in turn, formed the basis of a sound environment and prosperity.

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