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Depleting Water Resource in Urban Area

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Shrinking of Water Resource Due to Anthropogenic Activities in Urban Area
(A Case Study of Jaipur Using Remote Sensing and GIS)

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Abstract

There is a close relationship between the urban sprawl and water resources development. Protecting surface water resources like lakes, rivers, streams, and ponds etc in the vicinity of urban area has become a very difficult task for urban planner and administrators because of increasing pressure of population and anthropogenic activities. The haphazard growth of colonies, slum squatters and unplanned land use has break down the natural flow of hydrological net work in the urban area. The present paper provides an overview of some of the effects that land use have on water resource quality as well as quantity. The paper investigate the effects of land use change (from rural land use i.e. forest, agriculture, pastoral and culturable wasteland to urban land use) on water resources in Jaipur urban area. The remote sensing and GIS technique methodology have been adopted to map out the changes brought by human activities particularly in the field of haphazard growth of colonies, unscientific land use and encroachments etc. It also suggests alternative strategy or plan to solve the present problem.

During the course of study a series of thematic maps covering physical parameters and anthropogenic activities have been prepared to depict the changes and it's impact on hydrology vis-à-vis urban development. The Jaipur City has experienced its expansion at the cost of peripheral arable land, productive and best ground water recharge zone. This process has resulted in conversion of arable lands into non-arable uses often for the construction activities, which results in to the extensive damage to urban hydrological system. As the urban areas spread the natural hydrological features like rivers, nallah, water bodies comes in the heart of the city and are subject to encroachments. This results in either completely or partly blocks of the system. Hence this process on one hand breaks the hydrological system and on other hand creates a permanent recurrent flood damage zone in the city area.

Introduction

Urbanization and industrialization has threatened the surface and groundwater resources in and around the urban areas. The unplanned growth of urban settlements and infrastructure development act as an obstacle in the path of water flow which ultimately hampers the recharge process of ground as well as surface water bodies in the area. This process has resulted in the conversion of water potential and agricultural lands into non-agricultural uses. Apart from the diversion of lands for non-agricultural uses, the extensive damage to ecology and environment due to industrial waste, pollution, and misuse of land can also be seen in the urban areas and its periphery. One other important impact is noticed on the natural hydrological system of the city. As the urban areas spread, the natural hydrological features like rivers, nallah and water bodies come in the heart of the city and people start encroaching upon them. It results in either completely or partly blocking of the system. Another important issue that many of the cities have experienced its expansion at the cost of flood risk because they are settled in low-lying areas or along the river/nalla. These lands are often parts of some watersheds or catchments of the water bodies or rivers / nallas flowing in urban environs. Hence this process on one hand breaks the hydrological system and on other hand creates a permanent recurrent flood damage zone in the city area.

Objective of the Study

The main objective of the study is to understand the anthropogenic activities that have negative or positive impact on water resources of Jaipur city. The study aims to asses the impact on water resources due to changes in urban morphology encroachments, unscientific land use, haphazard growth of colonies and emergence of slum etc. and also suggests strategy which would help to solve the problem.

Methodology

The study has been carried out on the basis of remote sensing as well as secondary data. The satellite data have been used to prepare thematic maps mainly landuse and water resource, a village wise data from revenue and census department have also been collected and used in the study. The maps have been prepared in GIS environment using Arc Info, MapInfo, ERDAS and Auto-CAD software. For preparing base maps I have used Survey of India Topographical Sheet on 1:50,000 scale. A GPS survey has been carried out to collect ground truth for interpretation of satellite data. I have also collected information from revenue department. The remote sensing data have been analyzed using statistical as well as computer mapping technique supported by field surveys. The field surveys have been conducted in two parts phases i.e. reconnaissance survey and detailed survey for ground truth collection and preparation of image interpretation key. A few sites have been re-visited after interpretation of satellite data for final verification.

Data Used

Three types of data have been used viz. (i) conventional data (ii) remote sensing data and (iii) secondary data from line departments.

(I) Conventional Data:

1. **Topographical Sheets (Survey of India) :-** Nine Topographical Sheets i.e. 45/N/9. 45/N/10, 45/N/13, 45/N/14, 45M/12, 45/M/16, 54/A/4, 54/B/1, 54/B/2 on 1:50,000 scale have been used for all purpose of basic geographical information.
2. **Census data :-** Census data of series 1971,1981,1991 and 2001 have been used for collecting detailed information at village level. Some information from cadastral map and *zinswari* have also been used.

(II) Remote Sensing Data:

The satellite data of the year 1986 (IRS – LISS II FCC) 1991 (IRS - LISS III FCC) have been used to draw information on landuse, geomorphology and hydrological features. IRS-LISS –III and IV for year 2003 data in the form of False Color Composite have been used.

Expansion of the Jaipur City

In 1728 A. D. when the wall city of Jaipur was founded its total area was about 4.81 sq. km. By 1930-31 the limits of the municipal area further extended out of the wall of city, and the total area reached to 9.6 sq. km. In1951 due to rapid increase in population the city area has been further expanded to 40 sq. km. During 1964, with the increasing demand of population problems associated with urbanization like living accommodation, traffic congestion, lack of sanitation and other amenities etc. there was a felt need of preparing a Master Plan of keeping the needs of the Jaipur city up to 1991. In 1965 a Master Plan of Jaipur city was prepared covering 125 revenue village of surrounding areas of Jaipur city were brought in the urban boundary. The total area reached to 115 sq. km. In 1972 and addition 132 revenue villages have been inducted in the urban area and the total area reached up to 385 sq. km out of which 153 sq. km was the urbanisable area and rest was to develop green belt around Jaipur. In the year 1995 the Master Plan was revised targeting the need of the year 2011. The Master Plan earmarked the notified urban area of Jaipur city to be 96,300 acres (385 sq. km.) out of which 38,400 acres (153.6 sq. km.) was the urbanisable area (40%) and 57,900 acres (231.4 sq. km.) as the green belt (60%).

Physical Environment of Jaipur

The city is surrounded by the Nahargarh hills in the north and Jhalana in the east, which is a part of Aravalli hills - ranges. To the south and the west of the city is prevailing hillocks but they are isolated and discontinuous in formation. The southern end of the city is open to plain and stretches far and wide towards sanganer and beyond.. The general slope of the Jaipur city and its surroundings is from north to south and then to south-east. Nearly all the ephemeral streams flow in this direction. Higher elevations in the north exist in the form of low, flat-topped hills of Nahargarh (587 meters). The overall trend is a decline of level from the areas bordering the hills in the north to plain in the south. The Slopes of the plain areas are in general gentle.

The natural drainage of the Jaipur city is largely affected by erosion. It shows intense gully erosion particularly in the northern hilly region. Dhund river and Amani Shah nala form a fork like drainage pattern in the confluence zone of which the major part of Jaipur city is situated. The Amani Shah nala, which originates from the western slopes of Jaigarh hills, flows northwards in the upper reaches, turns south and south-west in its middle course and flows towards east in a broad semi-circle. Finally it joins river Dhund further down stream. There is another small drainage system in the north foothills which is now a days discharging the city's waste effluents into an artificially impounded lake called the Jal Mahal (Man Sagar). Jal Mahal lake is a large cesspool now of effluent waste water changing its profile from muddy water mixed with effluents and sludge during rainy season to a dried large puddle surrounded by parched earthen floor during summer seasons.

Climatically, Jaipur is located in the semi-Arid Zone of India. It has characterized by high temperature, low rainfall and mild winter. The mean temperature of Jaipur is 36^0 varying from 18^0 C in winter (January) to 40^0 C in summer (June). Thus the January and June are the coldest and hottest months.. The normal rainfall of Jaipur is 600 mm; nearly 90 percent of which takes place in the summer monsoon period i.e. from June to September, the rest comes from the winter cyclones.

Hydrometeorology

The monsoon rainfall which contributes about 96% of total annual rainfall extends from June end till September, July and August being the wettest months. Based on chegodev's empirical relation, probability of exceeding of average annual rainfall is about 25% and normal drought 19.7% where as probability of reverse and most severe drought is almost negligible. Perusal of rainfall periodicity (Annexure-I) shows good rainfall spell between 1981 and 1983 (with a flash flood in 1981) whereas the time span 1984-89 witnessed a low precipitation/drought period. This low rainfall spell was broken in 1990. The rainfall during the period of 1990 to 1998 was generally good with the exception of 1991 and 1993 when the rainfall was slightly below mean annual rainfall. Again, between 1998-2001, the precipitation was below 40% of mean and the city is witnessing yet another drought.

Impact of Urban Growth on Hydrology

The hydrology of Jaipur is governed by physical characteristics of landscape and geology. The city is surrounded by hills, Intermountain valleys, pediments and sandy plains. In northern and eastern parts, the Aravalli hill ranges, trending north, South-East, West with intermountain valleys, constitute significant signatures of physiography. There are as many as 518 rivulets originates from these hill ranges out of which 398 are of 1st order, 92 2nd order, 25 are of 3rd order and 3 are of 4th order streams. In early stage, the city expansion was restricted to food hills only and no drainage system was disturbed. But as the expansion took place, people started filling, diverting and blocking the streams. At many places the natural streams were used to dump the garbage. As a result 150 streams out of which 113 1st order 37 2nd second order and 10 are of 3rd third order stream are blocked or filled for the construction purpose due to expansion of Jaipur city. It has a direct bearing on the availability of surface as well as ground water. Now the water of these streams goes waste as flood water in the street of urban areas or flows in the urban sewerage system. It creates local flood situation in low lying areas.

Destruction of Ground Water Recharge System

Groundwater is part of the Earth's water or hydrological cycle. When rain falls, a part infiltrates the soil and the rest evaporates or runs off into rivers. The roots of plants will take up a proportion of this moisture and then lose it through transpiration to the atmosphere, but some will infiltrate more deeply, eventually accumulating above an impermeable bed, saturating available pore space and forming an underground reservoir.

Direct human interventions have lead to reduction in groundwater recharge. These include: deforestation, destruction of local water systems and stoppage of river flows. Deforestation also leads to change in river flow regime in the affected area that also affects the recharge in the given area. There are larger and indirect human interventions that have also affected the groundwater recharge systems, that include urbanization and concretization of more and more land.

As the built up area increases means more area comes under concretization like houses roads, and other amenities. These areas are not suitable for ground water recharge as the concretized land does not allow water to penetrate and hence the ground water recharge area is reduced. The Table–1 reveals that the built area in 1986 was only 143.40 Sq. km. which was increased to 189.70 Sq. km. in year 2003. It mean the potentiality of recharge the ground water area has been reduced by 46.30 Sq. km. during last 17 years.

Table-1 Changing Urban Land use in different Years

S. No.	Major Land Use Category	Area (Sq. Km) Year 1986	Area (Sq. Km) Year 1991	Area (Sq. Km) Year 2003
1.	Built-up Area	143.40	163.32	189.70
2.	Forest Area	57.45	53.52	59.01
3.	Crop Land	217.03	205.80	185.05
4.	Waste Land	18.30	13.63	2.24
5.	Total	436.00	436.00	436.00

Source :- Based on Interpretation of Satellite Data

Second important impact of the expansion of built up area is seen in relation to hydro-geo-morphology. Most of the area, about 65 percent is covered by alluvial plain (crop, wasteland and forest) which is good for ground water probability and ground water recharge. Now it is clear from the table I that out of the total 65 percent alluvial area which was under agricultural and Waste Land has reduced by 48 sq. kms. This reduction has a negative impact on ground water. It is observed that the ground water of these area have also gone down by 5.97m in HCM Training institute, 1.69m in Jhotwara area, 1.81 m at Army Cant (study conducted by Rajasthan Ground water Board).

Table -2 Distribution of Wells and Tube Well in different Land Use Categories

S. No.	Major Land Use Category	Area (Sq. Km) Year 1986	Tube Wells	Wells	Total (Well & T. Wells)
1.	Built-up Area	143.40	545	244	789
2.	Forest Area	57.45	13	27	40
3.	Crop Land	217.03	1349	449	1798
4.	Waste Land	18.30	54	19	73
5.	Total	436.00	1861	739	2600

Source :- Based on Interpretation of Satellite Data

Table -3 Distribution of Wells and Tube Well in different Land Use Categories

S. No.	Major Land Use Category	Area (Sq. Km) Year 1991	Tube Wells	Wells	Total (Well & T. Wells)
1.	Built-up Area	163.32	725	289	1014
2.	Forest Area	53.52	33	34	67
3.	Crop Land	205.80	1083	404	1487
4.	Waste Land	13.63	20	12	32
5.	Total	436.00	1861	739	2600

Source :- Based on Interpretation of Satellite Data and GIS

Table -4 Distribution of Wells and Tube Well in different Land Use Categories

S. No.	Major Land Use Category	Area (Sq. Km) Year 1991	Tube Wells	Wells	Total (Well & T. Wells)
1.	Built-up Area	189.70	791	325	1116
2.	Forest Area	59.01	20	32	52
3.	Crop Land	185.05	1050	382	1432
4.	Waste Land	2.24	-	-	-
5.	Total	436.00	1861	739	2600

Source :- Based on Interpretation of Satellite Data and GIS

The other important observation linking to this phenomenon is that wells of this area which was getting recharge through various streams and was not concretized also got negatively affected. Table 2,3 and 4 reveal that the distribution of wells and Tube wells in the built up area was 789, 1014 and 1116 in the year 1986, 1991, and 2003 respectively. Due to expansion in the built up area all these wells and tube wells have been in the grip of water deficiency. Again the rate and speed of water recharge depend on the type of surface area being concretized. If the area is fully packed with the cement like in the wall city where no single feet area is left *Kutcha,* all is packed wall to wall then there is no chance of recharging the ground water. Otherwise the speed and volume of recharge is slow down as per the percent of area concretized.

Other ground water recharge potential zones are the open and agricultural land. These land are often plain and with loose sand which keep the velocity of water low and are helpful in percolating water. The agriculture area in the year 1986 was 217 Sq. km. which was about 50 percent of the total geographical area. In year 2003 it has been reduced to 185.05 Sq. km. The distribution of wells and tube wells in the same area was 1798 and 1432 respectively in the year 1986 and 2003.

Depletion of Ground Water

The above four tables show that with in 17 years of urbanization, building of roads, houses and commercial complexes, by encroaching upon the forest lands, agricultural fields, pasturelands and open wasteland has taken place at an unprecedented rate. This has reduced the open areas to a great extent. The open areas were formerly the useful places to soak the rainwater and percolate it down to recharge the aquifers. Hence the city sprawl has shrunk the vacant surfaces thereby affecting the rainwater supply to water-bearing rocks. The diminished aquifers have now lowered the water table. During the past five years, the water table has gone down by more than one meters per year into the tube-wells and this is alarming to the ecology of the city. Thus the city is in the 'dark zone' of water potentials.

Encroachment upon the forest lands and pasture lands by building residential and industrial areas in Jawahar Nagar, Tilak Nagar, Vishwakarma industrial area, Vidyadhar Nagar and Amba Bari has proved to be suicidal in the total ecological scenario of the city. The damage caused is irreversible. Not only the water table has gone down in these areas, but also the natural abodes of wilderness have been lost forever. Today, all these areas are the most potential sources of ground water but the loss of rainwater replenishments to the subsoil layers is having a constant telling-effect to the extent that the vegetation and water resources will soon vanish.

In addition to above, advances in technology have also resulted in enormous increase in abstraction of ground water world-wide thereby disturbing natural ground water resource balance. Large-scale ground water development due to electrical mecanical process of water exploitation has rendered most of the Jaipur Urban area as over-exploited. The ever-increasing pace of development of ground water has also resulted in declining trends in water levels thereby causing decrease in the yield of the wells.

Degradation of Hills and Water Bodies

There are hillocks even within the towns. These hills provided a natural scenic view to the town. The population pressure has adversely affected these hillocks by removing vegetation for constructing purpose there by they are almost barren. The hill terraces are dotted with encroachments and unauthorized constructions. Extensive removal of vegetation particularly due to deforestation on the slopes of hills and from stable dunes flanking the hills has played a major role in degrading the environment. Due to stone quarrying from the hill slopes of Jhalana and Amagarh and also due to encroachments by way of urban construction activities, the problem of soil erosion has accelerated today. The quarrying has increased the degree of slope of hills causing deterioration in aesthetic view of hills.

Suggestions to Augment and Restore the Urban Water Resources

Conservation of Surface Water

Many major water ponds of the villages and their drainage which have not come under the influence of urbanization should be protected and keep their water course intact so that when they comes in the periphery of urban area they can be used as a source of surface water;

There are as many as 17 anicuts in the urban territory. There maintenance is very poor. The irrigation department do have sufficient fund to repair these structures, but they do note care. The urban area is facing acute water shortage. Hence their maintenance should be ensured;

There are a number of traditional water harvesting structures like step wells. Baories, Wells and Taals. Their condition is also poor. Recently Govt. of Rajasthan has shown interest to revive them in the name of conservation of Cultural Heritage. All these structures which are not in use due to lack of maintenances should be revived.

Conservation of Ground water

Advances in ground water exploitation technology have resulted in enormous increase in abstraction of ground water world-wide, thereby disturbing natural ground water resource balance. Large-scale ground water development due to urbanization and industrialization has rendered most of the Jaipur urban area ground water system as over-exploited. Recharge to ground water is also diminishing because of the shrinkage in the open areas. The ever-increasing pace of development of ground water has also resulted in declining trends in water levels thereby causing decrease in the yield of the wells.

Construction of Sub-Surface Barriers / Check dams

In order to arrest monsoon run-off rain water in the urban area of Jaipur, a number of subsurface bariers / check dams across the ephemeral Amanishah nalla and associated streamlets may be constructed. These structures within the impoundment area will allow speedy percolation of the water. Construction of such structures are likely to result in additional recharge of ground water.

Roof Top rain water Harvesting

Keeping in view the depleting water resources there is an urgent need for harvesting rooftop rain water for ground water recharge so as to minimize run-off water and evaporation losses. There is as much as 263.17 sq. km settlement area available for collecting water as roof top rain water. Hence govt. should seriously think to make a plan to conserve this water. Recently the Central Ground Water Board has initiated artificial recharge by rooftop rain water harvesting from the major buildings in the urban agglomerates. On experimental basis rain water harvesting project has been taken up at CGWB, WR, office building. The rain water from building rooftop is connected through pipe line and stored in a pit. The water in the pit will be allowed to percolate downward through a recharge tube well . The rain water harvesting by this method is cheaper as well as effective so as to store and recharge ground water.

Ground Water Regulatory Measures

Ground water exploitation needs to be regulated. In the peripheral areas of the urban agglomerate, utilisation of ground water for irrigation purposes should be practiced by employing sprinklers / drip methods only.

Registration of drilling agencies, existing ground water abstraction structures must be made mandatory. Seeking of permission for further construction of Ground Water abstraction structures also be made mandatory so as to control exploitation and protection of ground water from overdraft and quality degradation.

Industrial Sector

All most all the industrial area is run by using ground water. There by the ground water of these areas are depleting fast. The effluent of these industries may be treated and supplied to the agriculture field for irrigation purpose or this may be connected with dry well to recharge the ground water.

Domestic Sector

These are some suggestion by which one can save the water in day-to-day work.

- Reuse of domestic wastewater for gardening.
- Bathing just with a bucket of water instead of using fountain/Bath tub, that can save water to the tube of 100 lits. per day person.

- Using value system in toilets rather than flushing tanks that can save about 10 liters of water per person per trip.
- Making use of just ½ a liter container for saving instead of flowing water from taps thus conserving water to the time of about 4-5 litres per shave.
- Small container may be used for brushing teeth. Stop using taps for this purpose.
- Don't waste water from taps from washing clothes. A bucket of water may be sufficient for such washing.
- Leakage's from pipelines for water supply to urban/rural areas be checked properly by the concerned organizations/ societies.
- Construction of hand pumps may be further encouraged ground water exploitation by hand pump saves water.
- Try to restore the traditional ground water harvesting structures.
- Promote rainwater storage tanks/ tanks.

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