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Shrinking of Water Resource in Udaipur, Rajasthan (India) Basin using Multi-Temporal Satellite Data

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Abstract: Udaipur City, the city of lakes is facing an acute problem of the drying of its lakes. These lakes for the past 500 years have been the principal lifelines of the Udaipur basin. Their drying up has caused a severe set back to the tourism industry and other economic activities in the region. Many causes are responsible for it. Some these include erratic rainfall, explosive population growth, encroachment of lake- beds and rapid urbanization. Measures need to be taken to save these lakes through water conservation techniques, construction of new link channels etc. Remotely sensed data provides a effective tool for the analysis of the problem.

Key words: Catchment area · Basin · Lakes · Landsat · LISSI · LISS III & LISS IV · Lineament · Population

INTRODUCTION

Water resources are important for the survival of a planet. As water is a prime resource, a basic need, it is essential to realise its full potential. It has always played a very important role in human life since its existence. All human activities are affiliated to water. Water is a supreme economic wealth besides its biological importance. It serves as an ideal medium for biochemical reactions so necessary for life. Thus water sustains life and regulates all important economic activities because of which it has been termed as the richest of all economic resources. However with the ever increasing population and growth in economic activities there has been an unprecedented pressure on available water resources. They are continuously shrinking due to their over exploitation and unplanned utilization causing a severe constrained of water resources. In the present paper an attempt is being made to study the shrinking water resources of Udaipur district lying in the western state of Rajasthan in India.

Study Area: The study area Udaipur Basin lies between longitude 73°36'51"E to 73°49'46"E and latitude 24°28'49" to 24°42'56" N (Fig. 1). It is a saucer shaped basin 22 km wide from east to west and 24 km long from north to south. It is wider in the south and tapers off northwards.

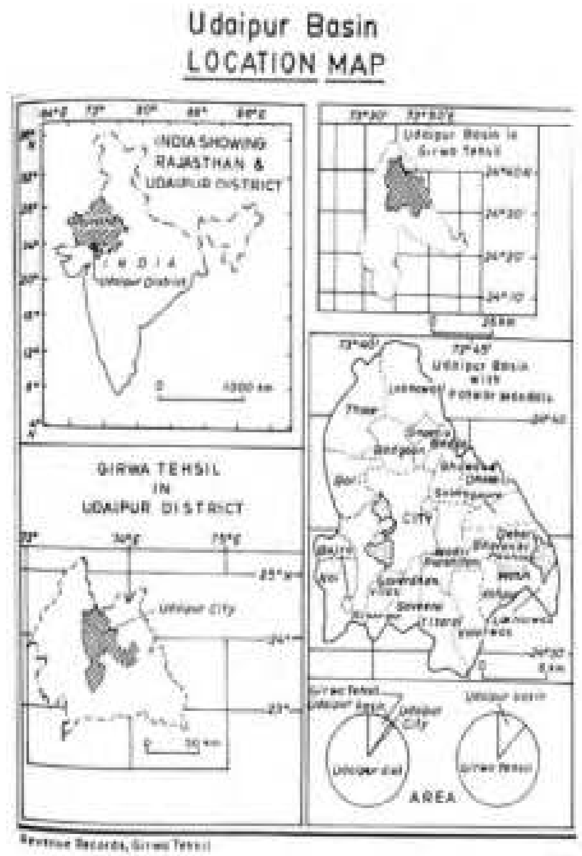

Fig. 1:

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Its average height is 577 meters above the mean sea level. The tropic of cancer lies 122 km to the south of the study area. Udaipur City popularly known, as the city of Lakes or Venice of the east is a picturesque city located to the south of the north-western state of Rajasthan in India. Founded by Maharana Udai Singh of Mewar in 1559 A.D. Udaipur is one of the most majestic and historical city with rich cultural heritage and diversity.

Problem under Study: Udaipur Basin is the recent years, (past fifteen years since 1999) has been facing an acute problem of drought. There is a severe water crisis. Both the surface and underground water sources have depleted considerably. The lakes have completely dried up causing a severe set back to the tourism, agriculture and other economic activities. The present paper is an attempt to make an in-depth study of the underlying causes of this critical situation and make constructive suggestions for future. Remotely Sensed data has been used for carrying out the current study.

MATERIALS AND METHODS

The present study has been undertaken with the help of Survey of India Toposheets of scale 1:25000 and 1:50000 surveyed in 1959-60, 1967-72 and 1973 respectively. Satellite images of varying resolutions for different years viz. Landsat MSS data of 3rd March, 1975 with 80 meters resolution, IRS data of LISS I of 18th February, 1996 with 72.5 meters resolution, IRS data of LISS III of 8th February 2004 with 23.5 meters resolution and IRS data of LISS-IV of 7th June, 2004 with 5.6 meters resolution have been used. The data of underground water of year 2014 has been used for analysis of underground water table for the study area. Besides this Geological Survey of India Map 1997 depicting lithological formation of the region has also been used. Ground truths have been verified through field survey. Secondary data pertaining to rainfall, irrigation, land use, population, lake water storage capacity, forest cover etc. have also been acquired from various governmental institutions.

For this study three broad methods have been used. Visual interpretation of remotely sensed data, mathematical analysis and field survey for verification of ground truth. The satellite data have been georeferenced. Digital Imaging Processing Techniques have been used for the demarcation of cropped area for the years 1975, 1996, 2004 and 2014. Catchment boundaries have been overlaid. Geological Map has been referred for lithological composition of the entire basin and a composite picture has been arrived at for analysis including lineaments, drainage, settlements and roads.

Physiography, Geology, Drainage and Climate: A brief insight into the physiography, geology, drainage and climatic conditions of the study area would not be out of place for an objective analysis of the problem. Structurally Udaipur basin is a saucer shaped basis in form of a deep valley surrounded by the Aravalli hill ranges which gridle it from all sides. Locally it is called Girwa meaning a range of hills (Fig. 2).

Udaipur basin is largely dominated by Aravalli and post Aravalli geological systems with phylite and schist as dominant rock types. The main city area lies on soft and cleaved metamorphic rocks of phyllite, schist and metagraywacke [1]. The rocks of upper catchment area are composed of phyllite, schist, basic volcanics and pyroclastics with enclaves of metaconglomerate and marble. Traces of limestone, lineaments and granite are found in the west along Sisarma River. The satellite image (IRS P6) of February 2004 depicts three prominent set of lineaments, trending NE-SW, NW-SE and EW directions around Udaipur City. These lineaments represent fracture zones in the area. The lineaments control the drainage and act as conducts for water seepage/ recharge of the lacks in the basin. These are however no faults and folds in the Udaipur lake region to cause any underground seepage from the lakes.

The region is drained by river Ahar and its tributaries. This is the only major river that flows through this region. It originates from the hills of Gogunda lying in the North West of Udaipur City, flows for a distance of 30 km and joins Udaisagar in the East. It is joined by numerous tributaries and subtributaries. Sisarma River with its tributaries Amarjok and Kotra is one such important tributary that merges into the Picchola Lake in Udaipur City. The Ahar River and its tributaries are seasonal in nature, they flow only during the rainy season and remain dry for the rest of the period. The basin is characterized by typical pinnate drainage pattern. Ahar River lies at the centre and its tributary form in dendritic pattern. India's principal water divide passes over 610 m contour towards west of Udaipur City.

Climatly Udaipur basin is transitional between semi-arid region in the north and sub-humid region in the south. It receives an annual rainfall of 65 cm, bulk of it is received during the summer season from the South West monsoons. Winters are dry with mild temperature and occasional cold waves. The nature of rainfall in the basin

Fig. 2:

Table 1: Udaipur Catchment of Lake Region (in Hectares)

Lake Region	Catchment Area
Bada Madar	8780.48
Chhota Madar	2987.23
Fatehsagar	4325.35
Bari Ka Talab	1906.55
Pichhola	14610.63
Goverdhan Sagar	814.63

Source: Based on Indian Topograhical Maps& Satellite data, RRSSC, Jodhpur

is highly erratic and uncertain. There is high variability in the amount of rainfall received. Consequently occurrences of droughts coupled with rainfall are a characteristic feature of the basin.

Keeping in view the above climatic conditions and limited natural water resources the erstwhile rulers 'Maharanas' of Mewar constructed several lakes in the Udaipur basin to overcome the problems of availability of water for the local population. These lakes are the principal lifelines of the residents of the basin. The Udaipur Lake region is divided into six major catchments (Table 1).

A brief description of the major lakes is given below:

Pichhola: It is the oldest amongst all the city lakes. It was constructed 600 years ago between 1382 and 1392 by Rana Lakha. This lake is situated in the southwestern part of the city at longitude 73°40' E and latitude 24°34' N. It derives its name from the village of 'Pichholi'. It accounts for a total water body area around 6.96 sq. km and has gross, live and dead capacities of 483, 318 and 165 meft, respectively. Its gauge height above and below sill level is 3.35 and 5.2 m. The lake has a maximum depth of 10.5 m. [2, 3, 4].

Rang Sagar: It was constructed in 1668. It is 1.03 km long and 245 m wide. It has a maximum depth of 7 m. It acts as a link channel between Pichhola Lake towards south and Swaroop Sagar and Fateh Sagar in the north. It's water holding capacity is 1000 mcft.

Swaroop Sagar: It is a pear shaped lake which was constructed in the year 1678. Its gross capacity is 427 mcft. Its live and dead capacity is 247 mcft and 180 mcft respectively. Its total area is 4.00 sq. km and has a maximum depth of 13.4 m.

Fatehsagar: Lake Fatehsagar is another principal lake of the city. The Lake is situated at longitude 73°37'E. and latitude 24°35' N at 578 m altitude (m.s.l.) in the north western side of the city. This pear shaped and medium sized lake was constructed by Rana Jai Singh in 1678 A.D. It was renovated in 1889 A.D. by Maharana Fateh Singh. The lake is 720m. long, about 100mwide and rises nearly 40 m from the ground level towards east. Fatehsagar Lake stretches 2.6 km in north-south and 1.8 km in east-west directions, covering a total water spread of nearly 4.00 sq. km and maximum depth of 13.4 m. It commands a total catchment area of about 41 sq.km. Its gross, live and dead capacity is 427.60, 247.60 and 180-mcft water, evidently lower than that of Pichhola.

Goverdhan Sagar: This lake is situated to the south of Pichhola at longitude 74°42' E and latitude 24°34' N. Its gross catchment area is 2.5 sq. km and its live capacity is 9 mcft. It is connected with Lake Pichhola through a link channel.

DISCUSSION

Udaipur Basin in the past six years (from 1999-2014) had been facing the problem of drought. The average rainfall during these years has remained below normal to the extent of more than 30%. This has severely affected the availability of water in the basin. Both the surface water and underground water resources got depleted. The lakes became dry, large proportions of the basin have turned into a dark zone. Almost all the lakes, the lifelines of the basin bore a deserted look. Recurring droughts are not uncommon in the basin. However it is for the first time in the past 85 years that such a prolonged drought has taken place in the basin. This prolonged drought in the result of multiplicity of causes, which are discussed below:

Table 2: Decenial Growth of Population in Udaipur City (1921-2001)

Year	Population	Variation during 1921-2001 in: Persons	Percentage
1921	34789	+1560	+4.69
1931	44035	+9246	+26.58
1941	59648	+15613	+35.46
1951	89621	+29973	+50.25
1961	111139	+21518	+24.01
1971	161278	+50139	+45.11
1981	232588	+71310	+44.21
1991	307682	+75094	+32.28
2001	490142	+182460	+59.30
2011	685245	+215103	+39.80

Source: Collectorate, Statistical section, Udaipur census, 2001

Population Explosion: At the outset there has been an explosive population growth in the Udaipur basin (Table 2). An analysis of the population growth of the past 80 years (1921-2001) shows that population increased from 34, 798 in 1921 to 49, 0142 in 2001, the year in which last census was held. Thus population has increased by 1308% over 1921. The decennial growth rate of population also shows an unprecedented growth trend. For example between 1921-1951 the decennial growth increased from +4.69 to +50.25%. Thereafter it declined to 24.01% and again increased to +45.11% between 1961-71. It reached a peak level increase of 59.30% between 1991-2001 and also 2001-2011 population growth increased from 59.30 percent to 39.80 percent [5].

This explosive growth of population has increased the demand for water causing severe depletion of both surface and underground water resources. From the statistics of water consumption requirement it is inferred that per capita water requirement for domestic purposes is 135 liters per day currently [2, 3]. At this rate the total water required for domestic purposes would be 27.10 million cubic meters in 2005. Another 9 million cubic meters would be required for industrial purposes totaling to 36 cubic million meters or 1271 million cubic feet water. As against it only 997 million cubic feet of water is available from all sources thus causing a deficiency of water.

Fig. 3:

Fig. 4:

Depletion of Forests: Another reason for the prolonged drought is the depletion of the environment of Udaipur basin. Forests have been recklessly destroyed from the catchment area of the lakes [6, 7]. In the past 45 years between 1960 and 2004 almost 60% forest cover has been removed from the surrounding Aravalli hill ranges which now bear a deserted look. This is clearly visible from the visual interpretation of the satellite image of 1975, 1996, 2004 and 2014 (Figs. 3, 4, 5 & 6). This has resulted in the decline of the rate of evapotranspiration and increased soil erosion.

Urbanization: Rapid growth of population in the last 50 years has led to a rapid expansion of urbanization in the basin [4, 8]. The extent of urbanization can be gauged from the fact that the municipal limit of Udaipur city has been revised six times between 1948 and 2001. The area has increased from 17.75 km^2 in 1948 to 61.10 km^2 in 1991, an increase by 248%. It has further increased to 91.52 km^2 in 2001 an increase by another 50% in mere 10 years. The expansion of urban area is clearly reflected in the IRS P6 LISS satellite image of February 2014 (Fig. 6). This has led to a severe encroachment of the catchment and lake bed region. Excessive dumping of the urban waste has converted River Ahar into a dirty ditch at many places along its course prominent examples of such encroachment are at Roopsagar Tank, Naila Talab, Fateh Sagar, Pichhola, Kalaliya Talab, Titardi, Madar Basin etc.

Erratic Rainfall: Udaipur basin lies in the Semi Arid Zone. It receives moderate rainfall averaging 65 cms annually. Bulk of it (95%) is received from the Southwest

Fig. 5:

Fig. 6:

Monsoons from June to September [9, 10]. Some rainfall is also received during winters under the impact of western disturbances, however the amount received is negligible. Rainfall here is characterized by high variability and erratic occurrence. If we analyse the annual rainfall data for the past 85 years from 1921 to 2005. It will be seen that 53 years recorded below normal rainfall and only 32 years recorded normal or above rainfall. Within these 53 years of deficient rainfall continuos drought for 3-year period has been a common feature. It has occurred 8 times in the past 85 years, besides there have been two 4- year period droughts and the last six years from 1999-2004 has been the longest period of drought in the last 85 years. In past six years (1999-2004) rainfall has been abnormally low, it has been 36.61%, 31.07% and 40.61% below normal rainfall in the years 1999, 2000 and 2002, respectively (Table 3). This has caused severe drought in the Udaipur Basin. In the last 15 years between 1991-2005 aridity in the region has increased the percentage of rainfall deficient years has increased by 2% from 60% to 62% and the rainfall surplus years has declined by 2% from 40% to 38% (Table 4).

Expansion of Agricultural Area: Agriculture is an important activity in the Udaipur Basin. There are many valleys and some flat areas in the lakes catchment area which are being intensively used for cultivation. Over the years there has been a rapid expansion in the cultivated area in the catchment area as given in the Table 5.

Table 3: Yearly Rainfall Data of Udaipur Basin (in mm)

Year	Rainfall	+ / - percentage change
1999	412	- 36.61
2000	448	- 31.07
2001	523	- 19.53
2002	386	- 40.61
2003	606	- 6.76
2004	576	- 11.38
2005	711	+ 9.38
2008	395	- 44.44
2010	415	+ 5.06
2014	448	+ 7.95

Source: Irrigation Department, Udaipur

Table 4: Udaipur City - Annual variation of Rainfall 1921-2014

	Number of years in		
Variation categories in %	Surplus rain	Deficient rain	Total
Less than 10%	6	16	22
10 - 20	7	12	19
20 - 30	6	8	14
More than 30%	13	17	30
Total	32 (38%)	53 (62%)	85 (100%)

Source: Irrigation Department, Udaipur

Table 5: Udaipur Basin, Cropped Area in Lake Catchment Region

		Cropped area (Area in hectares)				
				Based on satellite data		
S.No	Catchment Name	Catchment area	Topo Map Crop area (1959-60)	3rd March, 1975	18th Feb., 1996	8th Feb., 2004
1	Bara Madar	8780.48	335.00	397.37	608.67	509.76
2	Chhota Madar	2987.23	205.20	117.74	293.30	276.48
3	Fateh Sagar	4325.35	841.80	1187.39	1279.90	631.07
4	Bari ka Talab	1906.55	117.70	43.63	124.05	204.88
5	Pichhola	14610.63	1283.90	1102.76	1604.73	1480.84
6	Goverdnan Sagar	814.63	97.60	38.90	70.43	31.33
	Total area	33424.87	2881.20	2887.79	3981.08	3134.36

Source: Based on Indian Topographical Maps & Satellite data, RRSSC, Jodhpur

The total cropped area in the lake catchment region in 1959-60 was 2881.20 hectares, which was 8.6% of the total catchment area. It increased to 2887.79 hectares in 1975, 3981.08 hectares in February, 1996 but declined to 3134.36 hectares in February, 2004 as revealed by the satellite data. Thus in a period of 36 years the cropped area increased to peak a level of 3981.08 hectares, an increase by 38.17 percent in 1996 over 1959-60, but declined to 3134.36 hectares in February, 2004 which was however still 8.7 percent higher then the cropped area in 1959-60. An analysis of the cropped area in the individual catchment area of different lakes also clearly reveals the trend of expanding cropped area for example in case of Bara Madar the cropped area increased from 335 hectares in 1959-60 to a peak level of 608 hectares in 1996 an increase by 81% over 1959-60. In February 2004 it declined to 509 hectares which was still 51% more then the cropped area in 1959-60. Similarly in the catchment area of Pichhola the largest lake of Udaipur city the cropped area increased from 1283.9 hectares in 1959-60 to a peak level of 1604.73 hectares in February, 1996 which was 25% more then the cropped area in 1959-60. In February 2004 through it declined to 1480 hectares but it was still 15.35% higher then the cropped area in 1959-60 [9, 10]. The catchment of Fatehsagar also shows the same trend in 1959-60 the cropped area was 841 hectares, which increased to a peak of 1279.90 hectares in 19965, an increase by 52.04% over 1959-60.

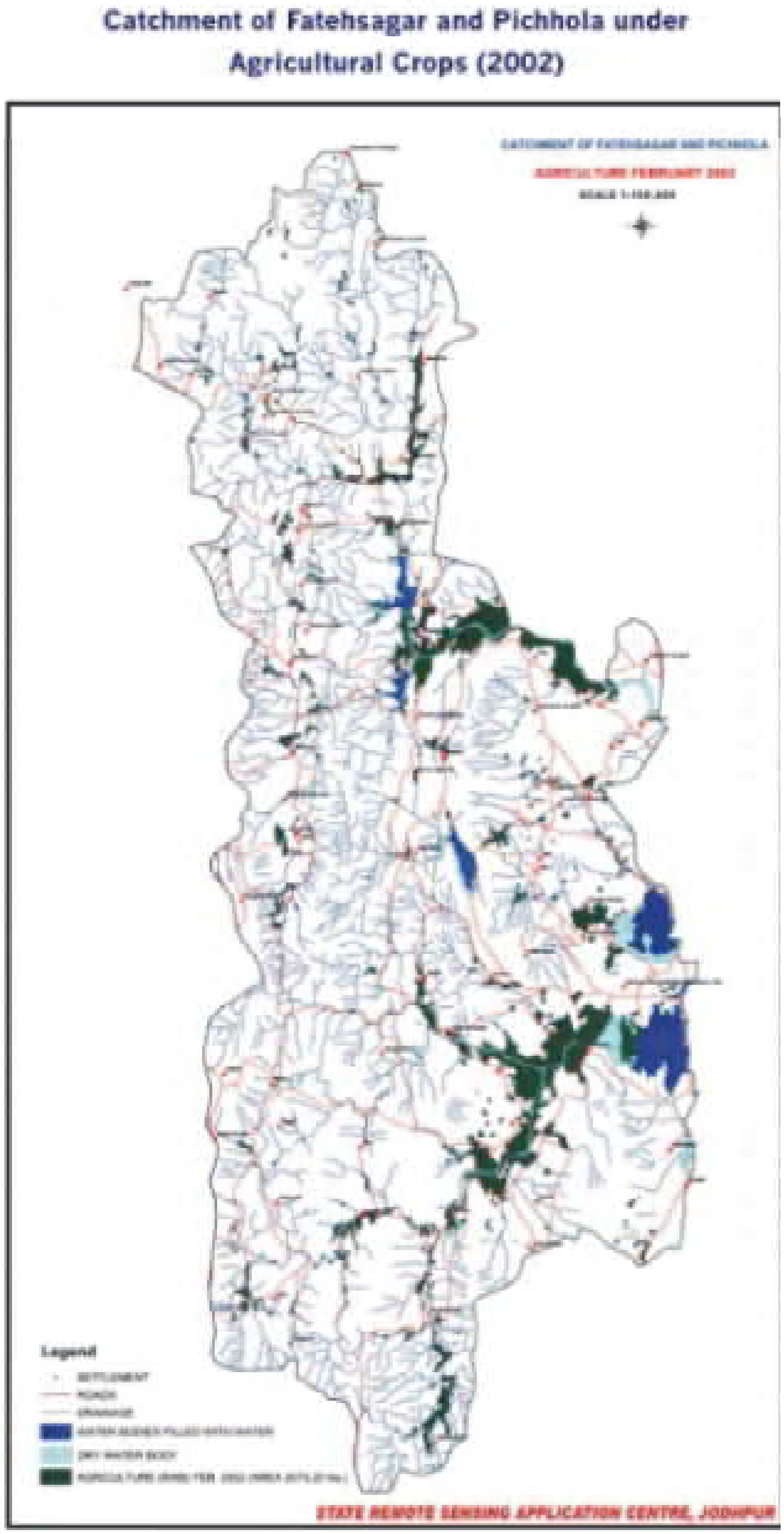

Catchment of Fatehsagar and Pichhola under
Agricultural Crops (2002)
Legend
STATE REMOTE SENSING APPLICATION CENTRE, JODHPUR

Fig. 7:

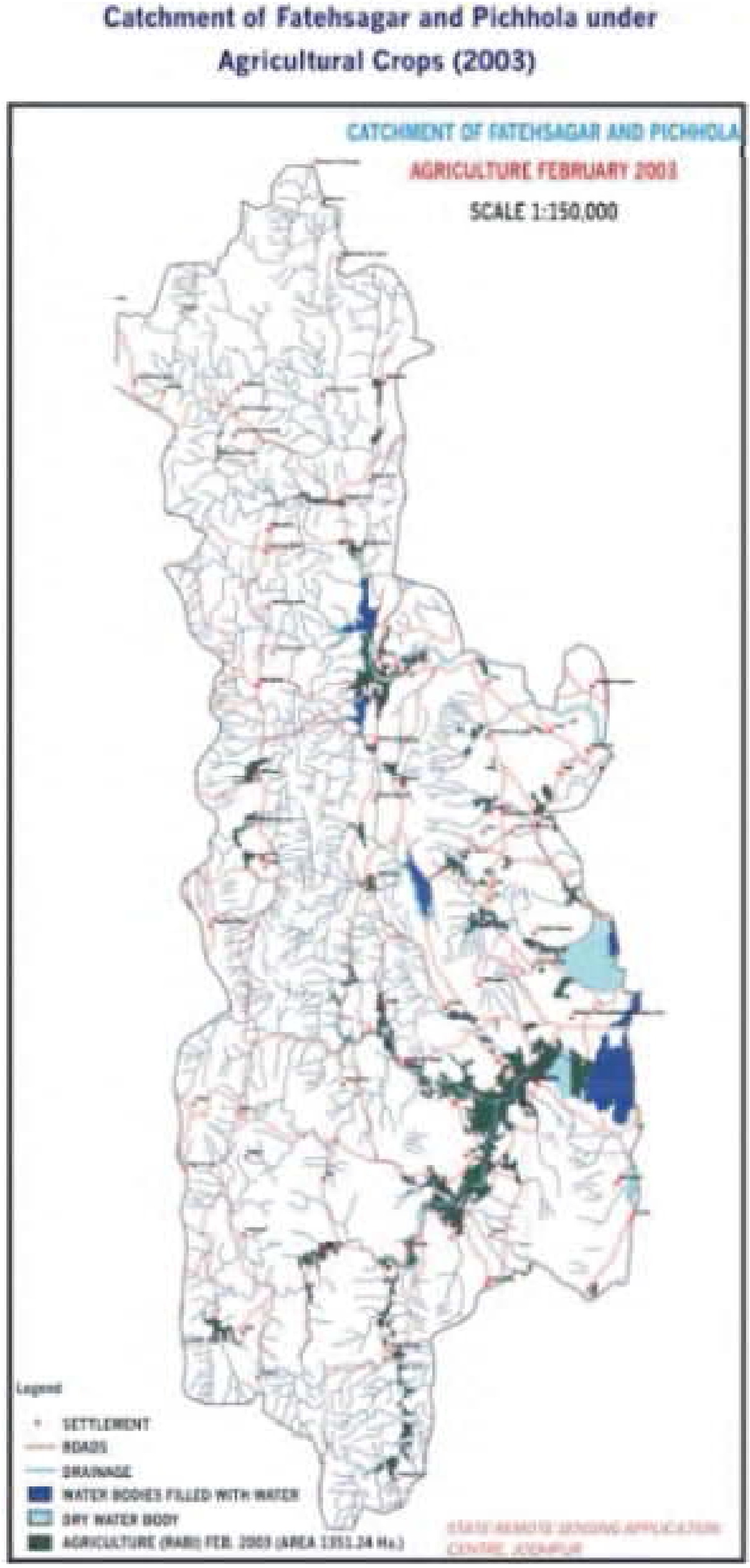

Catchment of Fatehsagar and Pichhola under
Agricultural Crops (2003)
CATCHMENT OF FATEHSAGAR AND PICHHOLA
AGRICULTURE FEBRUARY 2003
SCALE 1:150,000
Legend
SETTLEMENT
ROADS
DRAINAGE
WATER BODIES FILLED WITH WATER
DRY WATER BODY
AGRICULTURE (RABI) FEB. 2003 (AREA 1351.24 Ha.)

Fig. 8:

Catchment of Pichhola and Fatehsagar under Agricultural Crops (2014)

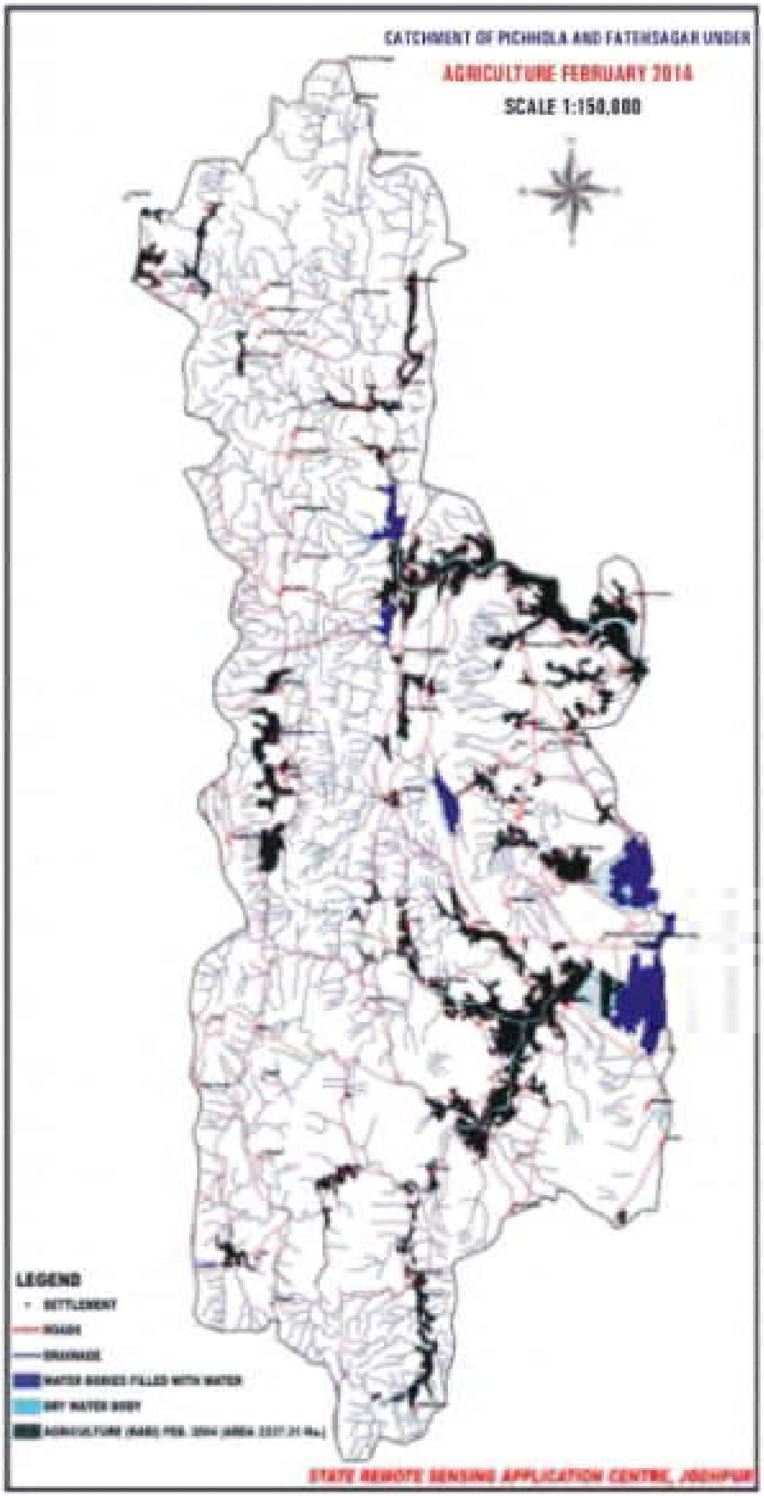
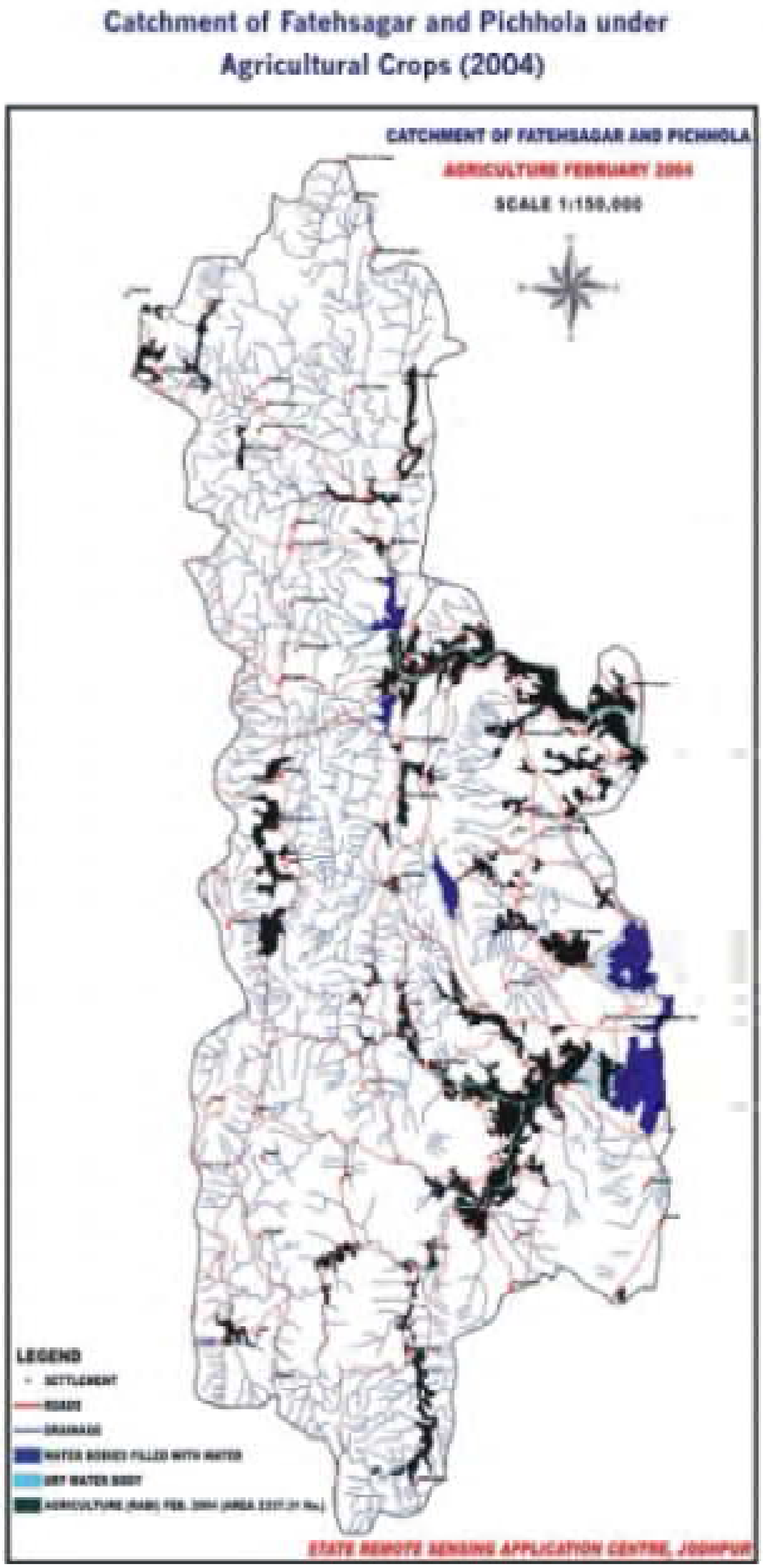


Fig. 9: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LEGEND
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ROADS
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DRY WATER BODY
STATE REMOTE SENSING APPLICATION CENTRE, JODHPUR

Fig. 10:

An important feature of the cultivation has been the rapid expansion of cultivated area in the lake bed region as revealed by the satellite imageries of the cropped area in the catchment of Fatehsagar and Pichhola, the two principal lakes of Udaipur city in the year 2002, 2003, 2004 & 2014 (Figs. 6, 7, 8, 9 & 10). The dry beds of the lakes and rivers have been used for intense cultivation that exhibits an excellent example of dry land farming rapid. This expansion of seasonal farming in and around the lake bed regions has however also caused adverse impact on the underground water and has also disturbed the surface symmetry.

Construction of Anicuts and Check Dams: Construction of anicuts and check dams across the major feeder drainage channels at several places has interrupted the free flow of rain water into the lakes. Consequently the lakes do not receive sufficient water from their catchment areas. Presently there are 53 anicuts built across these channels of which 23 are more then 2 meters high.

CONCLUSION

From the above discussion it is amply clear that the problem of drying of lakes is an acute problem which needs careful planning and water conservation measures. The lakes of Udaipur basin are an engineering marvel, which were constructed at the time when modern scientific techniques for the construction of the reservoirs were not available. Inspite of this, under the proper guidance and far sightedness of erstwhile rulers of Mewar led by Maharana Lakha, some of the most amazing and artistic pieces of engineering took their shape in the form of Pichhola, Dudh Talai, Kalaliya Talab, Rangsagar, Swaroopsagar, Fatehsagar, Udaisagar, Rajsamand and Jaisamand lakes. These lakes are unique as creation of man's interference with and modification of the natural drainage system. These lakes should be declared World Heritage.

Steps are needed to be taken to find a permanent solution to save these lakes. For this new linkages connecting these lakes with distant water bodies need to be developed which include Mansi, Wakal, Dewas and Mahi. In this regard the approach adopted by the erstwhile rules of Mewar need to be adopted. If we look at the construction, design and location of the lakes they are so built and connected that when one lakes gets filled the water is automatically released to the other lake thus maintaining water balance in different lakes. Also wasteful consumption needs to be avoided. Construction of anicuts across the drainage channels needs to be limited and encroachment of the lakebeds needs to be controlled.

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