Affectivity and Extent of *Haveli* Areas—A System of Water Prosperity

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Abstract: Agriculture sector is the major consumer of water. The water for agricultural activities is supplied either by surface water or ground water. Use of ground water is convenient as compared to surface water. In the present time, cropping pattern and agriculture system have become more water intensive. Both these factors disturbed the groundwater reserves. As a result in many areas of Madhya Pradesh, groundwater table is depleting at an alarming rate and there is an acute need of artificial recharge in those areas.

Private and public sectors both are engaged in increasing such recharge through introduction of recharge structures at appropriate sites throughout the State. However, it is observed that adaptability of recharge structures on individual level is very poor due to requirement of high initial investment. On the other hand recharge structures on community basis are not serving the purpose for many reasons.

The Haveli system of cultivation, a traditional method, was in practice since time immemorial in many parts of Madhya Pradesh, and utilized for conservation of moisture in the field for rabi crops. In Haveli system, cultivated fields surrounded by huge bunds are kept fallow during kharif season. Rainwater is collected in the fields and is retained for about three months and then drained in the month of October. Rabi crops are sown in the field after minimum tillage. This system helps in weed control also. The contribution of this system in groundwater recharge was either ignored, not known or was known to the wiser persons only and due to these reasons the system almost disappeared slowly in spite of all known benefits.

The present study is the first effort to mark the extent and affectivity of such a beautiful system in traditionally followed haveli areas. Sites selected for the study are Jabalpur and Narshingpur districts of M.P. Field data along with satellite data were used for assessing area under haveli storage during rainy season. Recharge from haveli fields computed from three locations showed average seepage from haveli fields as 6 mm per day. Infiltration characteristics and other physical characteristics of haveli fields were also obtained. A book keeping procedure for computing recharge from surface storage with corresponding daily rainfall for haveli fields was developed. The study conducted for the years 1989, 1997, 2000, 2002 and 2005 indicated recharge of 5.2, 27.2, 34.4, 29.5 and 46.8 cm during these years respectively. The respective rainfall of these years was 80.2, 111.5, 105.2, 112.8 and 163.3 cm. It was observed from remote sensing data that area under haveli was maximum (18,567 ha) in the year 2002, and minimum (4782 ha) in the year 2005 out of total 6,58,736 ha area. Haveli area was found to be 10 to 41% of cultivable area and 8 to 30% of total area under study.

INTRODUCTION

The State of Madhya Pradesh has a traditional water harvesting system locally known as Haveli. This is the system in which rainwater is collected and stored in the field itself by raising peripheral bunds. In the upper part of the Narmada valley, a unique cultivation system based on water harvesting and runoff farming still exists in some areas. The system was prevalent in Jabalpur, Narsinghpur, and parts of Damoh and Sagar districts covering an area of more than 1.4 lakh ha. But this system is most common in the Jabalpur-Narsinghpur tract and is locally known as the 'Haveli' system. Rainwater is held in embanked fields, enclosed on four sides until sowing time. Water is let out about one month after monsoon is over and as soon as land is dry, the fields are sown. After this no watering is required for the crops and it gets matured on the soil moisture stored in profile.

Area under Haveli system is not systematically documented in literature. The estimates made so far are just quantitative figures. Spatial distribution of this area is also not known. In order to locate and quantify the area under Haveli system, satellite data is useful since it gives better spatial resolution and energy in red and infrared bands, which is almost absorbed in the water body. Therefore, study was initiated to map the Haveli areas through satellite images.

REVIEW OF LITERATURE

Percolation pond and check dam help to recharge the ground water. Nedunchezhian et al. (2002) concluded that their limited storage capacity provide a limited augmentation in comparison to rainfall recharge. Alternate land use like pisci-culture with harvested runoff or recycling of such stored water will have ample scope for water resources development even in hilly areas (Satpathy, 2003). Ghildyal and Gupta (2002) reported the existence of haveli system in slow permeable soils like black clay soils. Tiwari and Dadhwal (2000) identified functioning of haveli system in Bundelkhand region, which covers an area of 7.0 mha. Haveli system was found a prominent technique of rainwater management in the study reported by Singh et al. (2003). They enumerated advantages like water conserving, weed control, organic carbon generating, availability of enhanced working period for tilling and seeding rabi crop and increase in productivity of post rabi crop, of haveli system.

Preliminary studies conducted at and around Jabalpur by scientists (Anonymous 2004, 2005) reported seepage quantification and estimation of extent of Haveli field in limited area of central India. Rajput et al. (2003) stated that excess water from haveli fields was drained out from other side of the fields to another field. The impounded water was stored throughout the kharif season and was drained 8 to 10 days before starting of land preparation of rabi crop. Farmers drain water from field through mogha drainage outlet.

Nema et al. (2003) stated that ground water depletes every year. The production and yield which we are getting today, is not sustainable and it is likely to reduce the precious water resource conserved in past few decades. Other programmes for conservation of water are not economic. Thus the revoking of the age old haveli system seems to be the only solution for the present problem of depletion of groundwater table and future of sustainable agent.

METHODS AND MATERIALS

In order to quantify rate of percolation from haveli fields, three sites were selected in haveli areas. The peculiar characteristic of haveli fields is that they have typical medium and deep black soils. The clay content ranges from 48% to 59% with bulk densities ranging from 1.41 g/cc to 1.49 g/cc and basic infiltration rates were measured and found as 0.2 cm hr^{-1} to 0.3 cm hr^{-1}. Water level depletion was measured with the help of gauges installed in the fields.

The recharge and storage of haveli fields were estimated adopting following book keeping procedure:

$$\text{Rainfall} - \text{Evaporation} = (1) - (2) = y_1 = (3)$$

$$\text{Calculate } MC_2 = \frac{(3)}{(BD \times D) \times 100} + MC_1$$

If $MC_2 > FC$, then $MC_2 - FC$ = Recharge (%)

Depth of recharge, Rd = Recharge (%) × BD

If Rd > y, where y = 4 mm, then, Rd − y = S

Add S to y_1 and repeat the procedure.

where MC = moisture content for day 1 or 2, BD = bulk density, D = depth of soil, FC = field capacity, y = water available for infiltration for day 1 or 2, S = storage over the surface and y = daily haveli recharge = 4 mm.

Satellite data were acquired for five years i.e, 1989, 1997, 2000, 2002 and 2005 pertaining to the study area which covers the haveli track. Table 1 presents the details of satellite, sensors, resolutions, date of pass and path row of the scene acquired.

Table 1. Details of the satellite data used for the study

Satellite	*Year*	*Sensor*	*Resolution (m)*	*Pixel size*	*Date of pass*	*Path*	*Row*
IRS 1 A	1989	LISS-2	36	36 × 36	6th Oct	26	51
IRS 1 B	1997	LISS-2	36	36 × 36	9th Sep	26	51
IRS 1 C	2000	LISS-3	24	24 × 24	13th Oct	100	55
IRS 1 D	2002	LISS-3	24	24 × 24	16th Sep	100	56
IRS P6	2005	LISS-3	24	24 × 24	6th Oct	100	55

RESULTS AND DISCUSSIONS

Hydrograph of three sites are presented in Figs 1, 2 and 3. The variations of rainfall are also shown in these figures. The water storage in the fields follows the rainfall pattern. Due to initial storms there was storage up to 80 to 100 cm in Beetli (Fig. 1), which was reduced to 25 cm and then again gained as and when rain occurred and it ranged from 40 to 60 cm, where as in another site at same location it ranged from 25 to 45 cm. At Karonda village storage depth ranged from 20 to 30 cm in initial period to 60 to 80 cm in peak time and then reduced to 30 to 50 cm at the end of season. Gauges installed in village Imaliya in Patan tehsil of Jabalpur also depict the similar trend of 20 to 45 cm storage. The observations were analyzed by considering rain-free days.

In Imaliya village, the percolation rate is found to be 1.3 cm/hr during initial monsoon period, which reduced to 0.6 cm/hr in later period of the monsoon. In Karonda village, block Kareli, the initial percolation rates were 1.0 cm hr^{-1} and did not change in later stage. In Beetli village, initial rates of 4.5 cm hr^{-1} reduced to 0.8 cm hr^{-1}. The reduction in percolation rate of Haveli fields as affected by the duration of monsoon may be attributed due to the saturation of the fields caused by the rainfall.

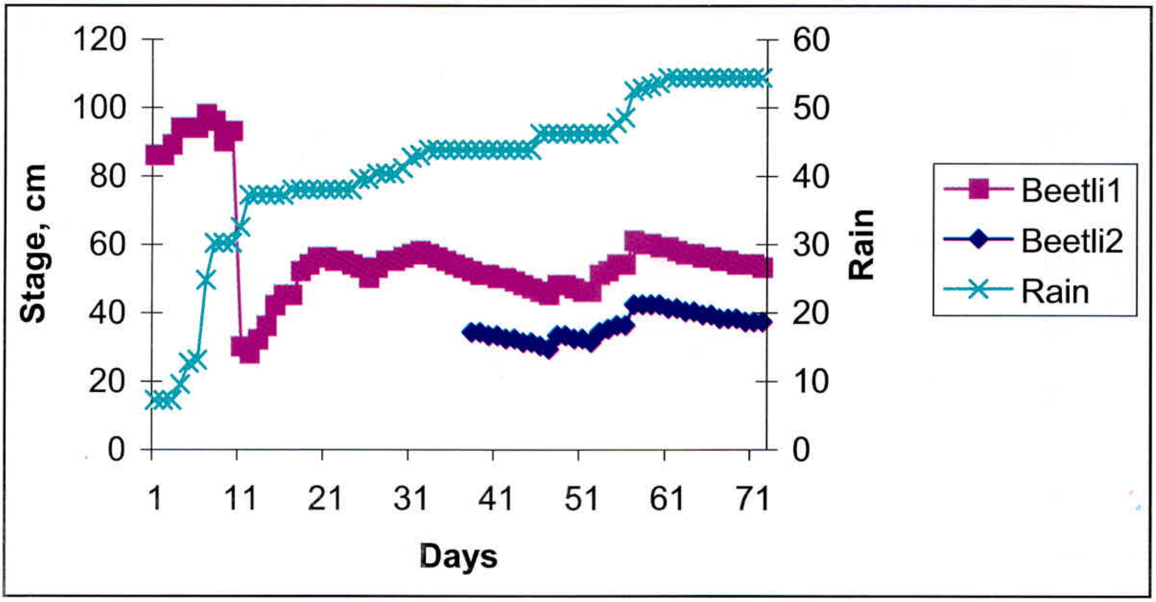

Fig. 1. Haveli gauging - Beetli.

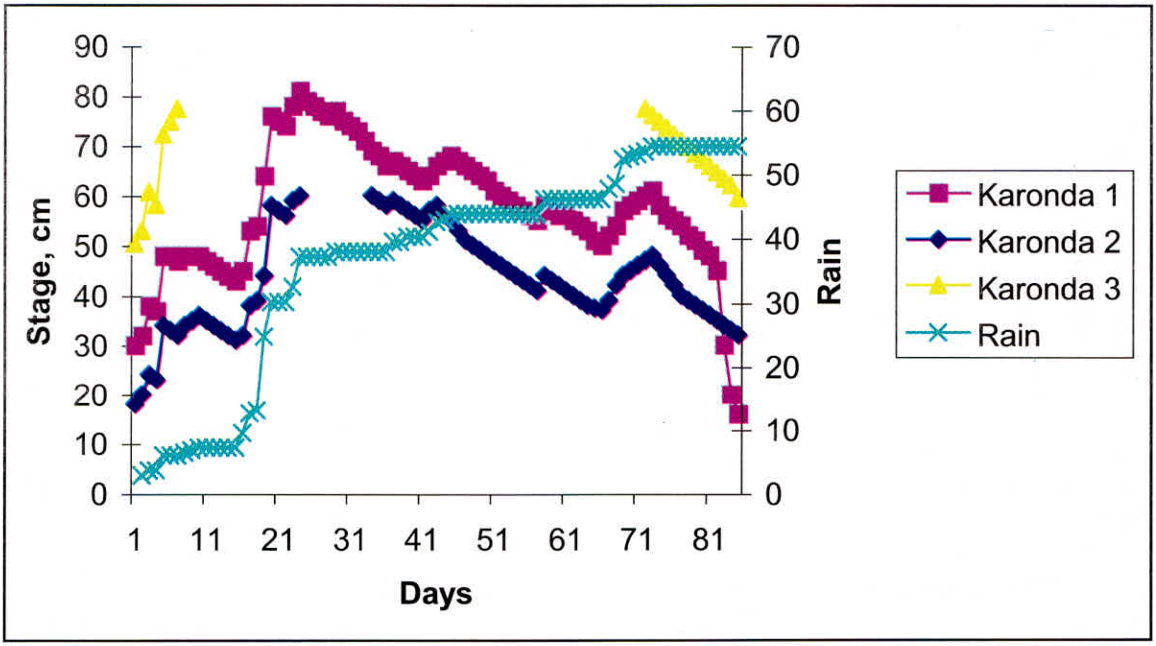

Fig. 2. Haveli gauging - Karonda.

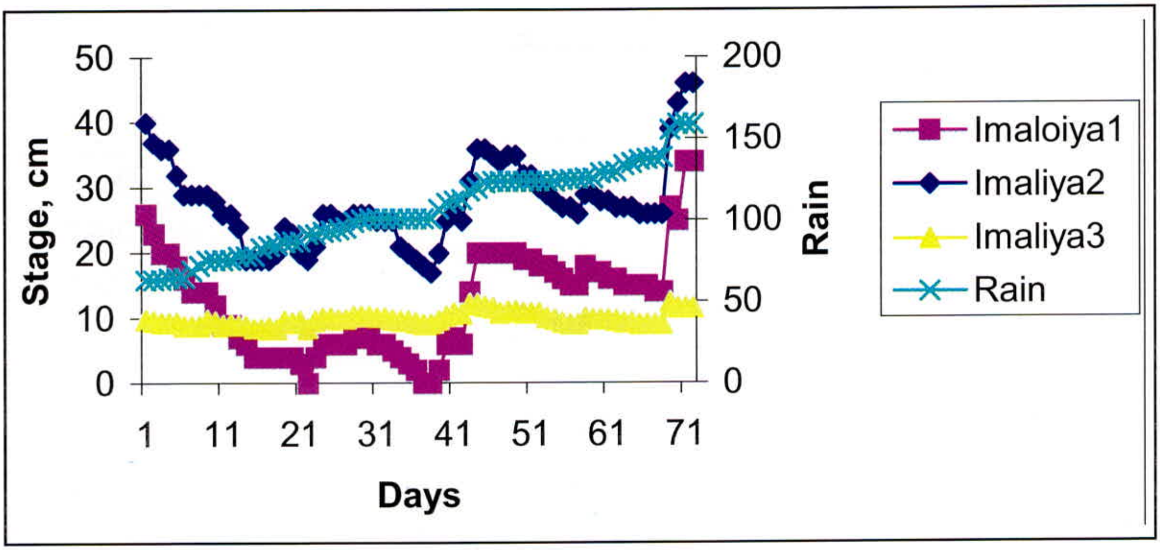

Fig. 3. Haveli gauging - Imaliya.

An estimate of recharge and surface storage with corresponding daily rainfall was prepared for the years 1989, 1997, 2000, 2002 and 2005. A representative estimate of the year 2005 is shown in Fig. 4. Table 2 shows values of daily rainfall, recharge and surface storage of all the years under study.

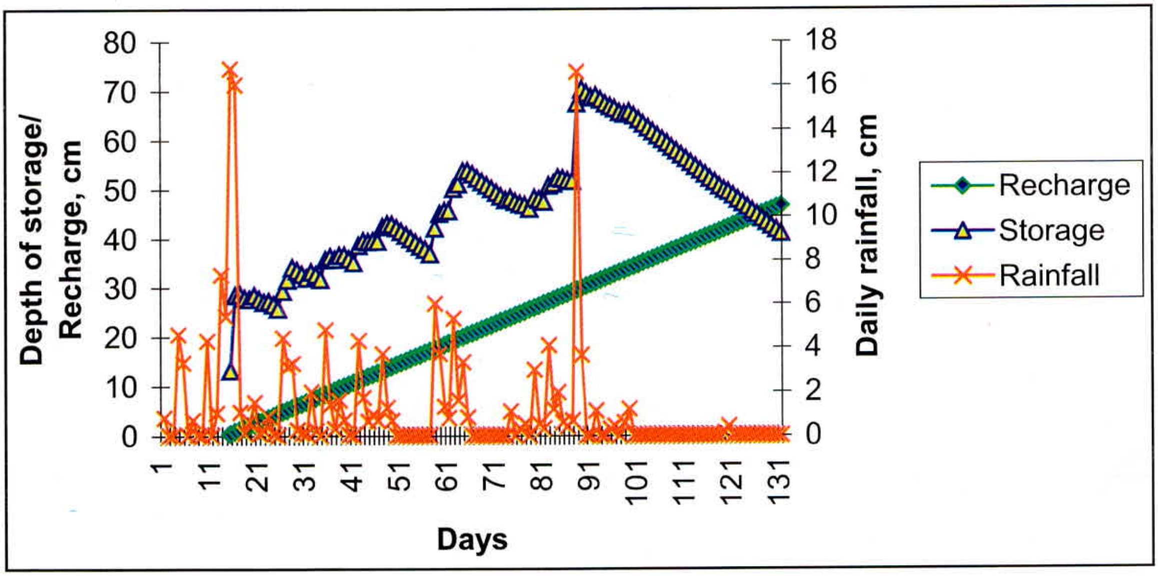

Fig. 4. Recharge through Haveli, 2005.

Table 2. Rainfall, recharge and surface storage in different years

Year	*Rainfall*	*Recharge*	*Beginning date*	*Max. surface storage*	*Surface depth at last date*
1989	80.2	5.0	10 Aug	4.9 14 Aug	0.0 18 Aug
1997	111.5	27.2	21 July	17.5 22 Aug	0.0 26 Sept
2000	105.2	34.4	20 July	17.9 28 July	0.0 14 Oct
2002	112.8	29.5	17 Aug	46.5 10 Sept	17.4 15 Oct
2005	163.33	46.8	5 July	70.4 17 Sept	41.1 29 Oct

The images were imported in ILWIS 3.0 software and georeferenced using toposheets obtained from Survey of India. The ground truthing was undertaken to identify the land area under different covers. Table 3 presents value of digital numbers for the different pixels under haveli and other cultivated areas.

Table 3. Digital numbers of the haveli and cultivated pixels in the study area

Year	*DN value*						
	H1	*H2*	*H3*	*C1*	*C2*	*C3*	*C4*
1989	22,66,42	16,56,42	36,87,76	246,25,59	183,56,47	95,45,42	49,87,76
1997	27,76,31	42,54,31	57,106,57	224,25,44	142,10,19	116,25,6	105,40,44
2000	36,16,117	48,63,142	98,144,194	195,40,149	139,45,149	127,49,156	
2002	10,64,127	25,71,145	43,88,139	196,21,99	149,14,84	165,64,136	84,24,107
2005	5,13,35	63,29,21	97,122,163	147,13,35	113,188,229	102,44,40	75,157,182

Georeferenced Images utilized to draw the sub map of the study area is given in Fig. 5. Sub map generated for the year 1997, 2000, 2002 and 2005 are presented in Figs 6 to 9 respectively. It can be observed from the image and corresponding histograms that area under haveli was maximum as 18,567 ha in the year 2002 and minimum as 4782 ha in the year 2005. The details of the derived land uses are presented in Tables 4 to 8. It can be observed that this percentage of haveli varies from 8% to 30% of total geographical area.

Table 4. Land use classification for the year 1989

S.No.	*Land use*	*No. of pixels*	*Area, ha*	*% of total area*
1	Cultivated land	268861	36807	58.8
2	Forest	30814	4218	6.7
3	Grassland	48054	6579	10.5
4	Haveli	81588	11169	17.8
5	Other	14959	2048	3.3
6	Pond	22	3	-
7	River	4101	561	0.9
8	Settlement	8670	1187	1.9

Table 5. Land use classification for the year 1999

S.No.	*Land use*	*No. of pixels*	*Area, ha*	*% of total area*
1	Cultivated land	226361	30989	49.4
2	Forest	47672	6526	10.4
3	Haveli	54153	7413	11.8
4	Pond	2834	388	0.6
5	River	812	111	0.2
6	Settlement	3775	517	0.8
7	Shadow	2035	279	0.4
8	Vegetation	117835	16132	25.7

Table 6. Land use classification for the year 2000

S.No.	*Land use*	*No. of pixels*	*Area, ha*	*% of total area*
1	Cultivated land	257755	14846	23.9
2	Forest	81729	4707	7.6
3	Grassland	89227	5139	8.3
4	Haveli	244520	14084	22.7
5	Other	380571	21921	35.3
6	Pond	62	4	-
7	River	6788	391	0.6
8	Settlement	17012	980	1.6

Table 7. Land use classification for the year 2003

S.No.	*Land use*	*No. of pixels*	*Area, ha*	*% of total area*
1	Cultivated land	93923	5410	8.7
2	Forest	391351	22542	36.2
3	Grassland	166943	9616	15.4
4	Haveli	322357	18568	29.8
6	Pond	15138	872	1.4
7	River	18533	1067	1.7
8	Settlement	72229	4160	6.7

Table 8. Land use classification for the year 2005

S.No.	*Land use*	*No. of pixels*	*Area, ha*	*% of total area*
1	Cultivated land	443633	25553	40.8
2	Forest	92642	5336	8.5
3	Grassland	391608	22557	36
4	Haveli	83087	4782	7.6
6	Pond	948	55	-
7	River	3419	197	0.3
8	Settlement	72834	4195	6.7

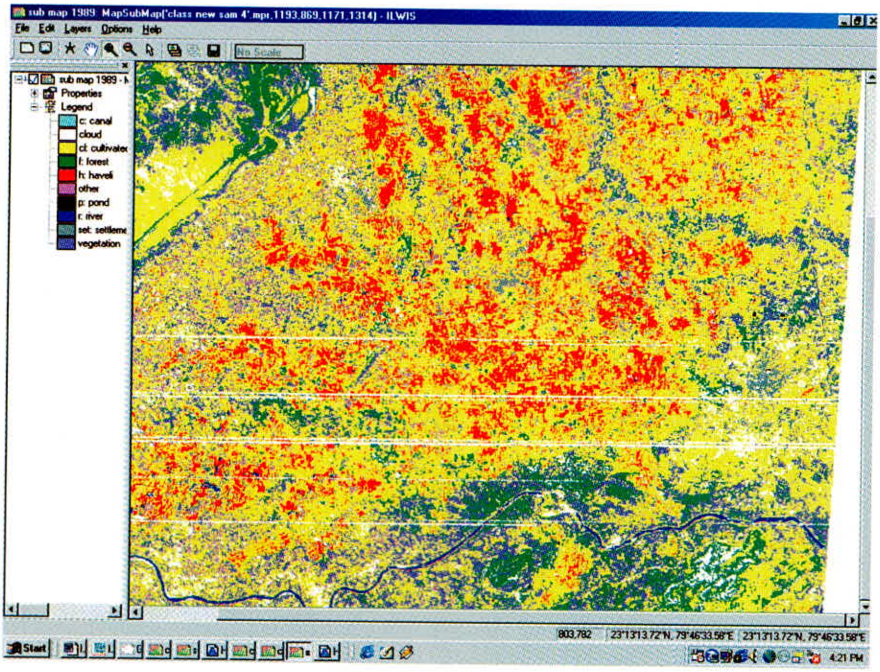

Fig. 5. Classified sub-map of study area for the year 1989.

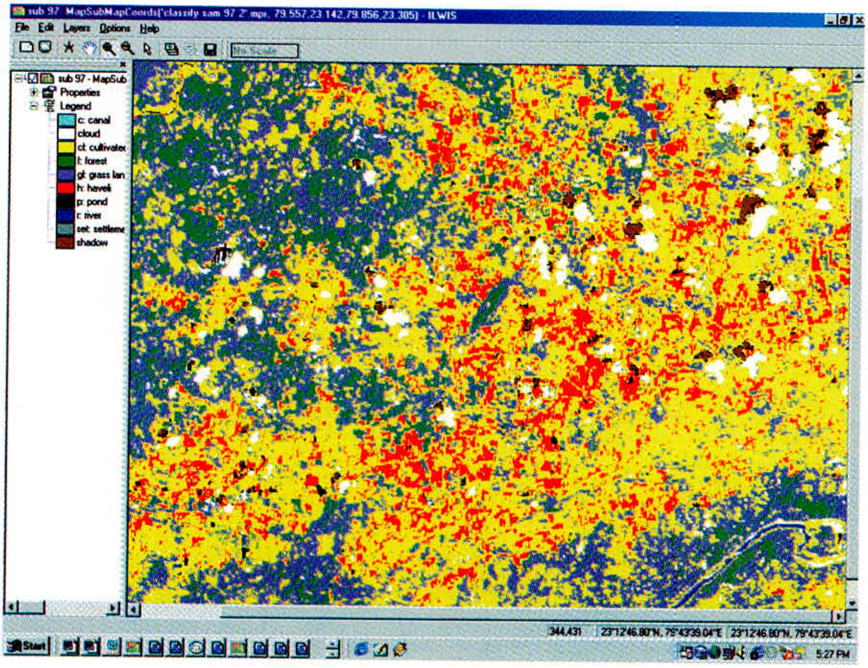

Fig. 6. Classified sub-map of study area for the year 1997.

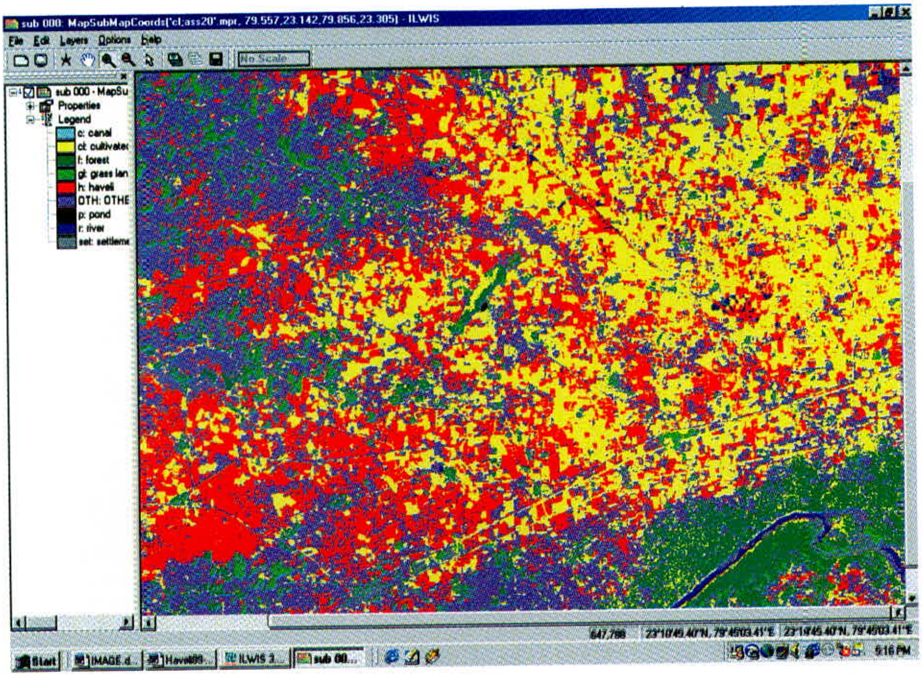

Fig. 7. Classified sub-map of study area for the year 2000.

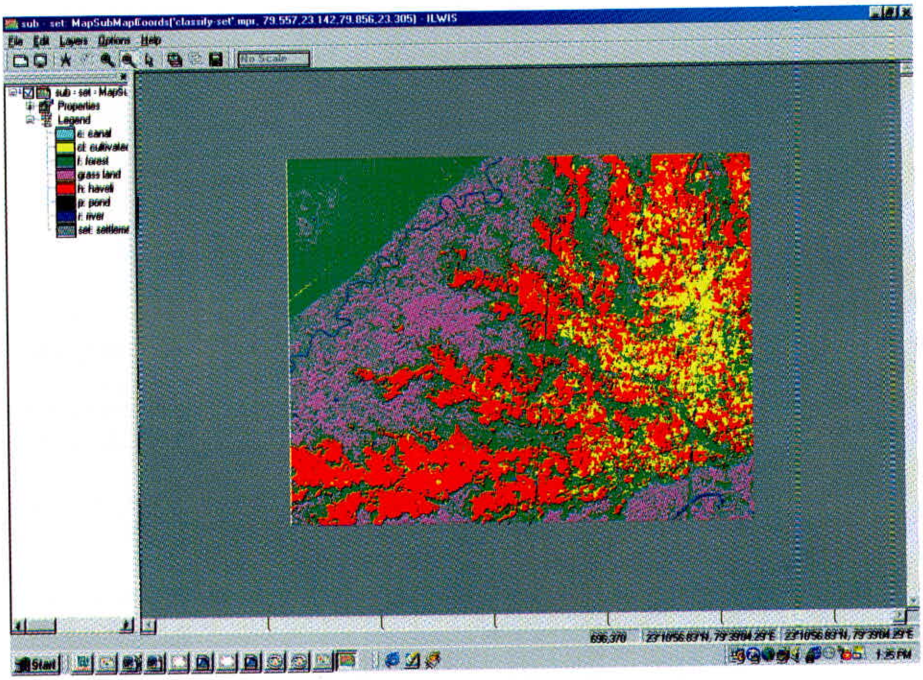

Fig. 8. Classified sub-map of study area for the year 2002.

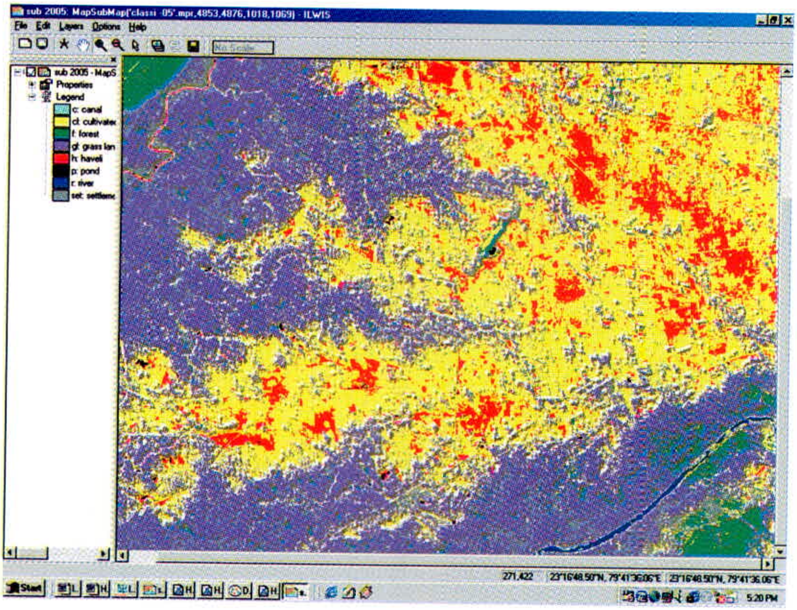

Fig. 9. Classified sub-map of study area for the year 2005.

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