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GIS Based Delineation of Micro-watershed and its Applications: Mahendergarh District, Haryana

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ABSTRACT A watershed is a logical unit of planning for optimal development of soil, water and biomass resources or it may be said that it is a basic unit for micro-level planning. In the present paper an attempt has been made to delineate sub-watershed and micro-watersheds in Mahendergarh district of Haryana. Data has been generated from Survey of India toposheets on 1:25,000 scale and multi-spectral satellite data of IRS P6. Watershed boundary has been delineated using ArcGIS 9.3 software. By using Arc-hydro tools, 40 micro-watersheds have been delineated. These can be used more conveniently in assessing ground water resources and execution of development programme at micro-level. After delineating micro-watershed, an attempt has also been made to study the landuse pattern of these micro watersheds. Monitoring of micro-watersheds through the knowledge of landuse pattern helps in management or in sustainable development of natural resources in that area in scientific manner.

INTRODUCTION

It is rightly said that water prosperity of our land lies in the adoption of watershed management. Water, land and biomass are the crucial components of watersheds. In the last two decades, watershed management has gained the top most priority for integrated water and land resources development. The watershed approach has become a pre-requisite for any developmental programme because land and water resources have maximum interaction and synergic effect when developed on watershed basis. Watershed approach is, therefore increasingly applied in various development programmes like command area development, soil and water conservation, flood control, soil erosion control, river valley projects, land reclamation, people and resource dynamics etc. It is equally important for various hydro-power and irrigation projects, assessment of ground water resources, pollution and artificial recharge studies. The literature also suggests economic sustainability, ecological sustainability and social sustainability as three major themes associated with watershed development approach. For proper planning and execution of any developmental programme on watershed basis, it is essential to map various attributes of a watershed.

What is Watershed*:* A watershed is a natural geohydrological unit which is drained by a part or totality of one or several given water courses. In other words watershed is a topographically delineated area draining into a single Channel. Hence it comprise of a catchment area (*Recharge zone*), a command area (*Transition zone*) and a delta area (*Discharge zone*) (Jain 2004).The literature suggests that watershed can be of various sizes depending upon the size of stream, drainage density and its distribution. But management of a watershed requires a suitable hydrological unit. It may also be noted that smaller hydrological unit or proper delineation of sub-watershed is a challenging task in arid topography.

In this context, present paper attempts to achieve the following objectives:

Objectives

1. To delineate watersheds, sub-watersheds and micro-watersheds in semi-arid area of South Haryana.
2. To study the landuse/landcover pattern of micro-watersheds and to understand the sustainability of existing landuse.

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STUDY AREA

Haryana state enjoys two river basins namely Ghaghar and Yamuna basins. Mahendergarh district, situated in south-western part of Haryana, has a geographical area of 1927.72 sq. km. The district is part of Yamuna basin, as reported in Soil and Landuse Survey (AISLUS 1988) and it has its own two watersheds of two seasonal rivers that is, Krishnawati and Dohan Rivers (Fig. 1). The climatic condition in the district varies from arid to semi arid. The summer months are very hot whereas, winter season is fairly cool and dry. The average annual rainfall of the district is 592.5mm. About 75 percent of annual rainfall is received during the south west monsoon in the months of. July, August and September. It is dominated by dry lands with presence of inland streams, sandy plains, shifting sand dunes, stabilized sand dunes, dissected upland tracks and often barren, denuded, rocky hill ranges and their outcrops. Overall relief is undulating with a regional slope.

Dohan and Krishanawati rivers make irregular flood plains in the district. The flood plain occurs in association with sandy terrain and dunes to variable morphology. These rivers after entering the district gradually shrink and loose water at high rate of evaporation and excessive percolation in sandy material. The rivers are active only during the rainy seasons which raise the fresh quality sub-soil water. The seasonal flow in Dohan and Krishnawati periodically raises the level of fresh quality subsoil water. Besides, it also helps base flow during early part of the dry season. Now since Rajasthan has made a number of dams in the upstream of the river, as a result there is no appreciable water in the rivers (Government of India 1991).

DATA AND METHODOLOGY

The paper is primarily based on secondary sources. Data has been generated from Survey of India (SOI) toposheets on 1:25,000 scale for creating micro-watershed by taking into account the topography of the study area. For this contours and drainage pattern of the district have been digitized in 2 separate layers. In order to obtain this, 23 toposheets on 1:25000 scale were required to mosaic the whole district. The landuse/landcover has been studied by taking multi-spectral satellite data of 2008. Satellite images of IRS 1D-LISS IV and PAN merged were utilized. In order to generate sub-watersheds, ArcGIS software has been used. Landuse/ landcover has been delineated using ERDAS image processing software. Landuse of the study area has been studied under 5 broad categories. These are (i) agricultural land, (ii) forest, (iii) waste land (comprising of open scrub and sand dunes), (iv) built-up area or settlements and (v) water bodies. Water bodies have been further classified as {water body (dry pond, fill pond and water course)}.

RESULTS AND DISCUSSION

1. Delineation of Watersheds

In order to demarcate a watershed in an area: one need all linear water features, an elevation or terrain model, the flow direction grids which may indicate the steepest descent etc. The purpose of terrain pre-processing is to perform an initial analysis of the terrain and to prepare the dataset for further processing (Chinnayakanahalli et al. 2006). A Digital Elevation Modal (DEM) of the study area is used as input for terrain pre-processing. In the present study DEM is generated using contours and interpolation of elevation data obtained from toposheets using algorithms (Fig. 2).

The DEM reconditioning function has been applied which modifies Digital Elevation Models by imposing linear features onto them. This is being done to check the accuracy of slope and existing drain lines (Tarboton et al. 2003). Since this area is also affected by stone quarrying and sand extraction, hence the topography has got modified. In order to nullify that in delineating natural watersheds, the fill sink function has been applied. This function fills sinks (unusual depressions/ elevations) in a grid. In higher elevation cell, the water is trapped in that cell and cannot flow. The fill sinks function modifies the elevation value to eliminate these problems. Further, the flow direction has been checked which computes the flow direction for a grid. The values in the cells of the flow direction grid indicate the direction of the steepest descent from that cell. Similarly, flow accumulation, Stream definition and Stream Segmentation functions have been used for this process. With the input of all these processes, catchments have been converted in to raster format. With the help of

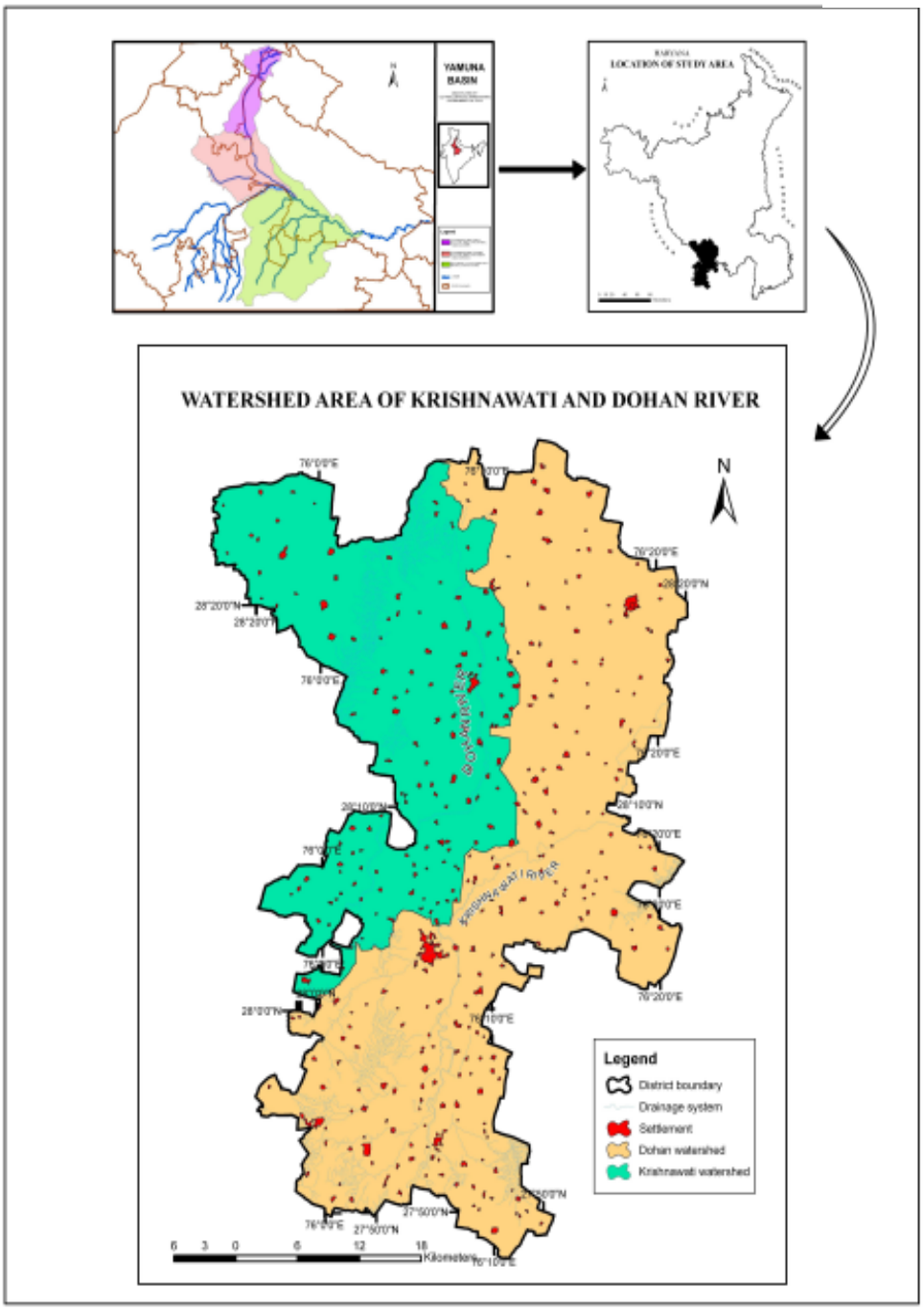

Fig. 1. Mahendergarh -Watershed area of Krishnawati and Dohan River

these catchment polygons, watershed boundaries have been generated.

In all, 40 micro-watersheds of various sizes have been delineated and are shown in Figure 3. It shows that among these 40 micro-watersheds, 15 are lying in Dohan sub-watershed and other 25 have been delineated in Krishnawati sub-watershed. The variation in size of each watershed is a characteristic of slope, drainage, lineament, geomorphology and associated factors. The size wise distribution of micro-watershed as depicted in Figure 3 and Table 1 reveals that the smallest watershed is of 4 km² and largest one is 128 km². There are 4 micro-watersheds which are as small as covering less than 10 km². Another 3 are covering 10 to 20 km² area. It may also be noted that due to varied topography of the area, 8 watersheds are quite large which constitute 40 percent of total sample study area.

Table 1: Characteristics of micro-watersheds (area in km²)

Size of micro-watershed	*Number of watersheds*	*Total area*	*Percent area*
Less than 10	04	25.28	1.31
10-20	03	47.77	2.48
20-40	13	427.08	22.15
40-80	12	627.43	32.55
80 and above	08	800.17	41.51
Total	40	1927.72	100.00

2. Landuse/Landcover

A comprehensive information on landuse/landcover is the basic prerequisite for land resource evaluation, assessment, utilization, and management. With increasing population pressure on land and the resulting changes in the landuse pattern and processes, a considerable degree of land transformation and environmental deterioration is being witnessed. Proper planning, management and monitoring of the natural resources depend on the availability of accurate landuse information. This also helps in understanding the human induced changes in the land use pattern in a particular area (Chaudhary et al 2008). In this context, landuse pattern of whole the district and of different micro-watersheds has been attempted. The landuse pattern of the whole study area of the year 2008 as delineated from satellite multi-spectral data is presented in Table 2 and Figure 4. It shows 5 main classes of landuse in the area. It indicates that 84 percent of its total area is under agriculture. Another 10 percent is waste land in the form of open scrub and sand dunes. Forest cover is 2.4 percent of total area. While settlements occupy about 2 percent, and only a minuscule, that is, (0.21 percent) is under water courses.

A detailed landuse pattern in all micro-watersheds of the year 2008 may be obtained from Table 2 and Figure 4. Among different land use classes, the one which cause problem in natural resource management is the existence of wasteland. Depletion of forest cover, presence of scrubs in the large area pose serious problem to the environment. This can be easily managed on micro watershed basis. Hence the land use pattern on micro watershed basis has been presented. It shows that there are three micro-watersheds lying in north and north-western part of study area (numbered as 5 and 6) and another lying in southern part of the study area (numbered as 36 and 38) where proportion of waste land is quite high that is, more than 40 percent. Size-wise these are middle level micro-watersheds and efforts can be directed for the treatment of land in these micro-watersheds. Among large micro-watersheds only one lying in north-

Table 2: Landuse/Landcover in Mahendergarh: 1974-76 to 2008 (area in km²)

Landuse categories	*1974-76*		*2008*		*Percent difference*
	Total	*Percent area*	*Total*	*Percent area*	
Agricultural land	1629.39	84.52	1670.515	86.66	2.14
Forest	46.33	2.40	47.160	2.45	0.05
Waste land	206.41	10.71	166.741	8.65	-2.06
Settlement	38.14	1.98	39.138	2.03	0.05
Waterbody (Dry Pond)	1.96	0.10	1.962	0.10	0
Waterbody (Fill Pond)	0.38	0.02	0.382	0.02	0
Waterbody (River Course)	5.11	0.26	1.826	0.09	-0.17
Total	1927.72	100.00	1927.72	100.00	

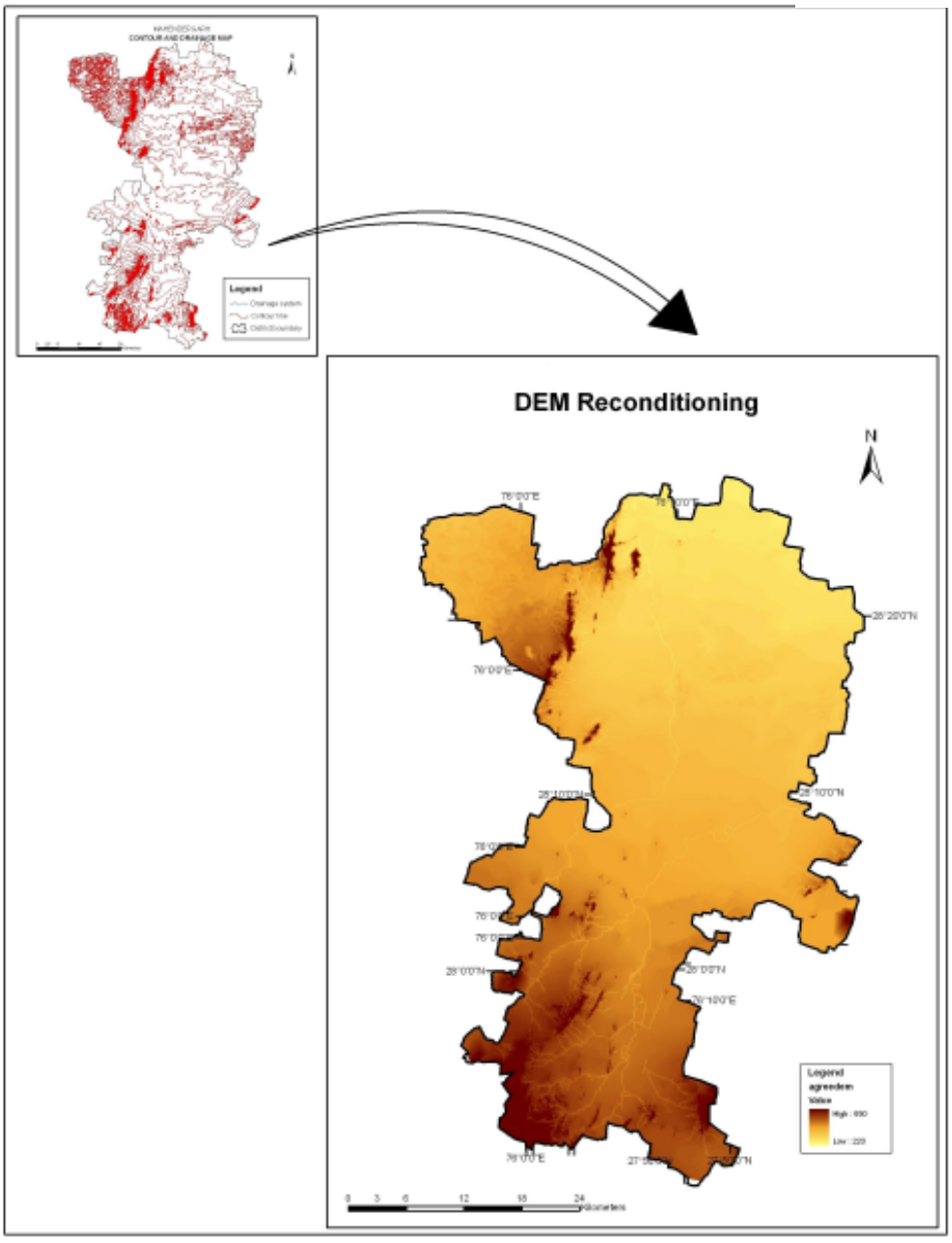

Fig. 2. Mahendergarh - DEM reconditiong

Table 3: Landuse/Landcover of all micro-watersheds (1974-76 to2008)

No. of Micro-watershed	*Total area*	*Percent area*	*Agricultural Land*		*Forest*		*Waste land*		*Settlement*		*Waterbody (Dry Pond)*		*Waterbody (Fill Pond)*		*Waterbody (River Course*	
			1974-76	*2008*	*1974-76*	*2008*	*1974-76*	*2008*	*1974-76*	*2008*	*1974-76*	*2008*	*1974-76*	*2008*	*1974-76*	*2008*
1.	37.271	1.93	34.530	35.786	0.000	0.000	2.345	1.089	0.372	0.372	0.020	0.020	0.004	0.004	0.000	0.000
2.	63.652	3.30	57.166	60.936	0.108	0.108	5.425	1.655	0.934	0.934	0.019	0.019	0.000	0.000	0.000	0.000
3.	30.306	1.57	28.181	28.795	0.193	0.193	1.473	0.859	0.414	0.414	0.044	0.044	0.001	0.001	0.000	0.000
4.	85.271	4.42	65.836	66.434	1.309	1.309	17.16	16.561	0.922	0.922	0.032	0.032	0.012	0.012	0.000	0.000
5.	6.067	0.31	0.030	0.030	1.741	1.741	4.296	4.296	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6.	22.922	1.19	13.033	13.033	0.371	0.371	9.193	9.193	0.315	0.315	0.000	0.000	0.010	0.010	0.000	0.000
7.	23.403	1.21	21.563	21.712	1.301	1.301	0.082	0.082	0.300	0.300	0.000	0.000	0.009	0.009	0.149	0.000
8.	51.915	2.69	35.808	36.912	2.805	2.805	12.859	11.763	0.387	0.387	0.041	0.041	0.007	0.007	0.008	0.000
9.	48.471	2.51	34.383	36.444	6.544	6.577	6.922	4.829	0.607	0.607	0.015	0.015	0.000	0.000	0.000	0.000
10.	68.975	3.58	59.979	61.865	3.501	3.501	0.976	0.272	3.327	3.327	0.010	0.010	0.000	0.000	1.182	0.000
11.	122.620	6.36	114.646	115.024	4.964	4.964	1.236	0.859	1.663	1.663	0.042	0.042	0.069	0.069	0.000	0.000
12.	59.966	3.11	53.908	53.975	0.654	0.654	4.106	4.038	1.188	1.188	0.038	0.038	0.072	0.072	0.000	0.000
13.	43.511	2.26	37.570	39.983	1.929	1.929	2.771	0.358	1.218	1.218	0.020	0.020	0.004	0.004	0.000	0.000
14.	32.790	1.70	25.994	31.122	1.131	1.131	5.171	0.043	0.482	0.482	0.014	0.014	0.000	0.000	0.000	0.000
15.	31.224	1.62	27.947	28.660	1.418	1.418	1.332	0.617	0.529	0.529	0.000	0.000	0.000	0.000	0.000	0.000
16.	127.930	6.64	114.174	121.145	4.187	4.288	7.202	0.130	2.333	2.333	0.027	0.027	0.008	0.008	0.000	0.000
17.	80.357	4.17	72.411	74.719	0.183	0.183	6.324	4.016	1.381	1.381	0.041	0.041	0.018	0.018	0.000	0.000
18.	85.094	4.41	78.125	79.204	1.735	1.735	3.639	2.560	1.499	1.499	0.096	0.096	0.000	0.000	0.000	0.000
19.	54.935	2.85	42.004	46.160	6.172	6.870	6.029	1.175	0.709	0.709	0.018	0.018	0.002	0.002	0.001	0.000
20.	114.189	5.92	98.283	103.405	1.932	1.932	9.775	6.602	2.182	2.182	0.044	0.044	0.024	0.024	1.948	0.000
21.	82.320	4.27	70.802	70.899	0.250	0.250	7.595	7.498	1.702	1.702	0.109	0.109	0.037	0.037	1.826	1.826
22.	29.872	1.55	26.307	26.353	0.000	0.000	2.985	2.939	0.551	0.551	0.000	0.000	0.028	0.028	0.000	0.000
23.	45.469	2.36	41.399	42.288	1.344	1.344	1.641	0.752	1.054	1.054	0.031	0.031	0.000	0.000	0.000	0.000
24.	37.788	1.96	35.346	35.429	0.423	0.423	0.698	0.615	1.296	1.296	0.026	0.026	0.000	0.000	0.000	0.000
25.	34.980	1.81	31.188	31.329	0.334	0.334	2.872	1.731	0.533	1.533	0.051	0.051	0.002	0.002	0.000	0.000
26.	74.983	3.89	67.071	67.075	0.373	0.373	5.747	5.743	1.594	1.594	0.196	0.196	0.002	0.002	0.000	0.000
27.	12.738	0.66	10.686	10.686	0.000	0.000	1.719	1.719	0.332	0.332	0.000	0.000	0.000	0.000	0.000	0.000
28.	102.388	5.31	89.422	89.422	0.180	0.180	8.388	8.388	4.245	4.245	0.141	0.141	0.011	0.011	0.000	0.000
29.	4.196	0.22	3.044	3.044	0.000	0.000	1.036	1.036	0.115	0.115	0.000	0.000	0.000	0.000	0.000	0.000
30.	55.785	2.89	42.477	42.477	0.000	0.000	11.945	11.945	1.122	1.122	0.237	0.237	0.004	0.004	0.000	0.000
31.	18.296	0.95	12.492	12.492	0.000	0.000	5.495	5.495	0.305	0.305	0.005	0.005	0.000	0.000	0.000	0.000
32.	42.786	2.22	40.754	40.757	0.000	0.000	0.986	0.983	0.927	0.927	0.098	0.098	0.021	0.021	0.000	0.000
33.	38.078	1.98	29.054	29.069	0.000	0.000	8.54	8.526	0.457	0.457	0.023	0.023	0.005	0.005	0.000	0.000
34.	25.215	1.31	22.607	22.607	0.000	0.000	1.652	1.652	0.831	0.831	0.123	0.123	0.002	0.002	0.000	0.000
35.	6.574	0.34	5.008	5.008	0.000	0.000	1.378	1.378	0.140	0.140	0.048	0.048	0.000	0.000	0.000	0.000
36.	37.743	1.96	19.106	19.106	1.246	1.246	16.619	16.619	0.647	0.647	0.115	0.115	0.009	0.009	0.000	0.000
37.	31.675	1.64	21.149	21.149	0.000	0.000	9.974	9.974	0.410	0.410	0.122	0.122	0.020	0.020	0.000	0.000
38.	8.442	0.44	4.650	4.650	0.000	0.000	3.51	3.510	0.281	0.281	0.000	0.000	0.000	0.000	0.000	0.000
39.	30.792	1.60	28.786	28.851	0.000	0.000	1.313	1.248	0.610	0.610	0.084	0.084	0.000	0.000	0.000	0.000
40.	16.733	0.87	12.468	12.479	0.000	0.000	4.006	3.995	0.227	0.227	0.031	0.031	0.000	0.000	0.000	0.000
Total	1927.72	100	1629.386	1670.515	46.327	47.160	206.413	166.741	38.138	39.138	1.962	1.962	0.382	0.382	5.113	1.826

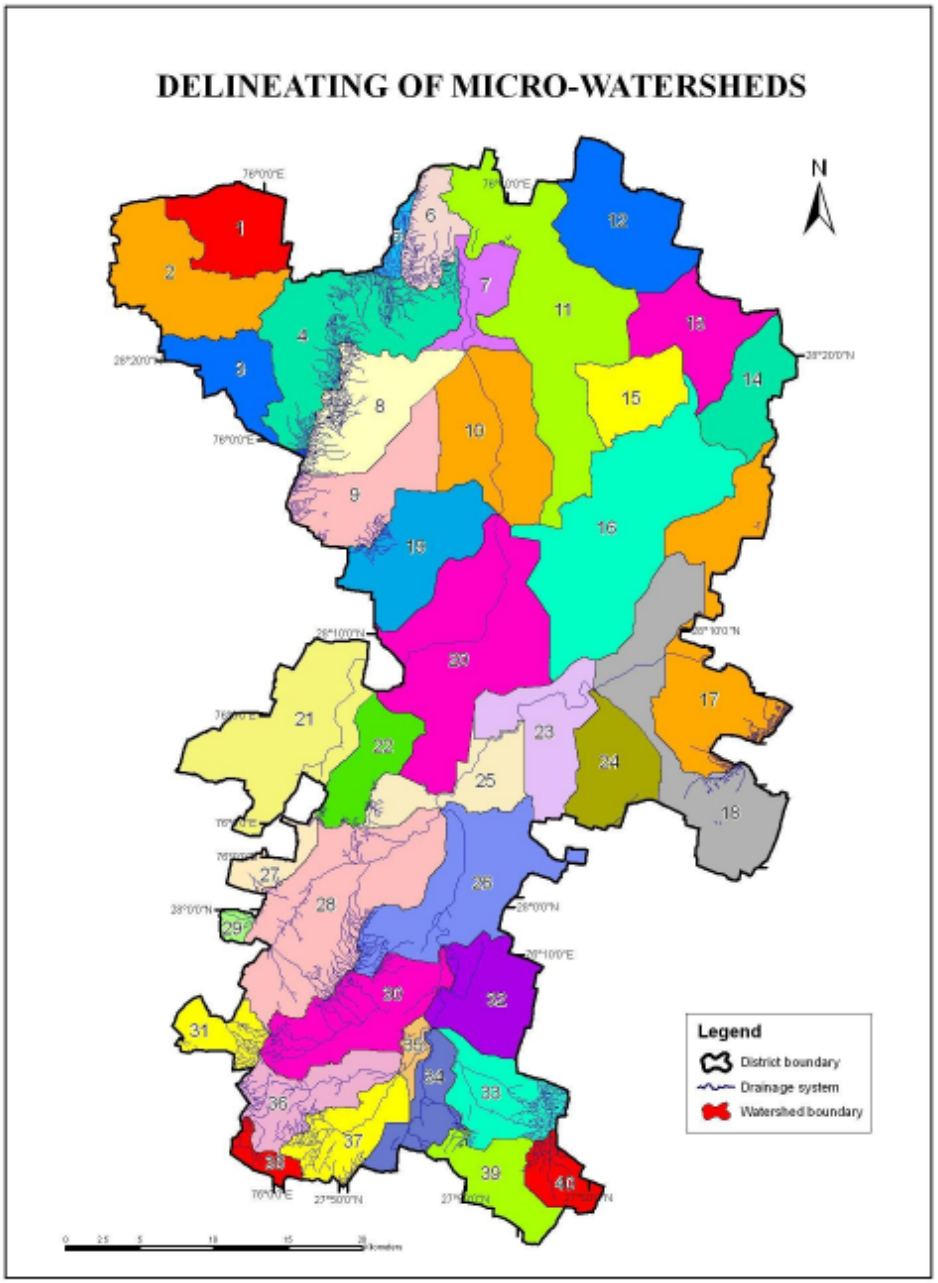

Fig. 3. Mahendergarh - Delineating of micro-watersheds

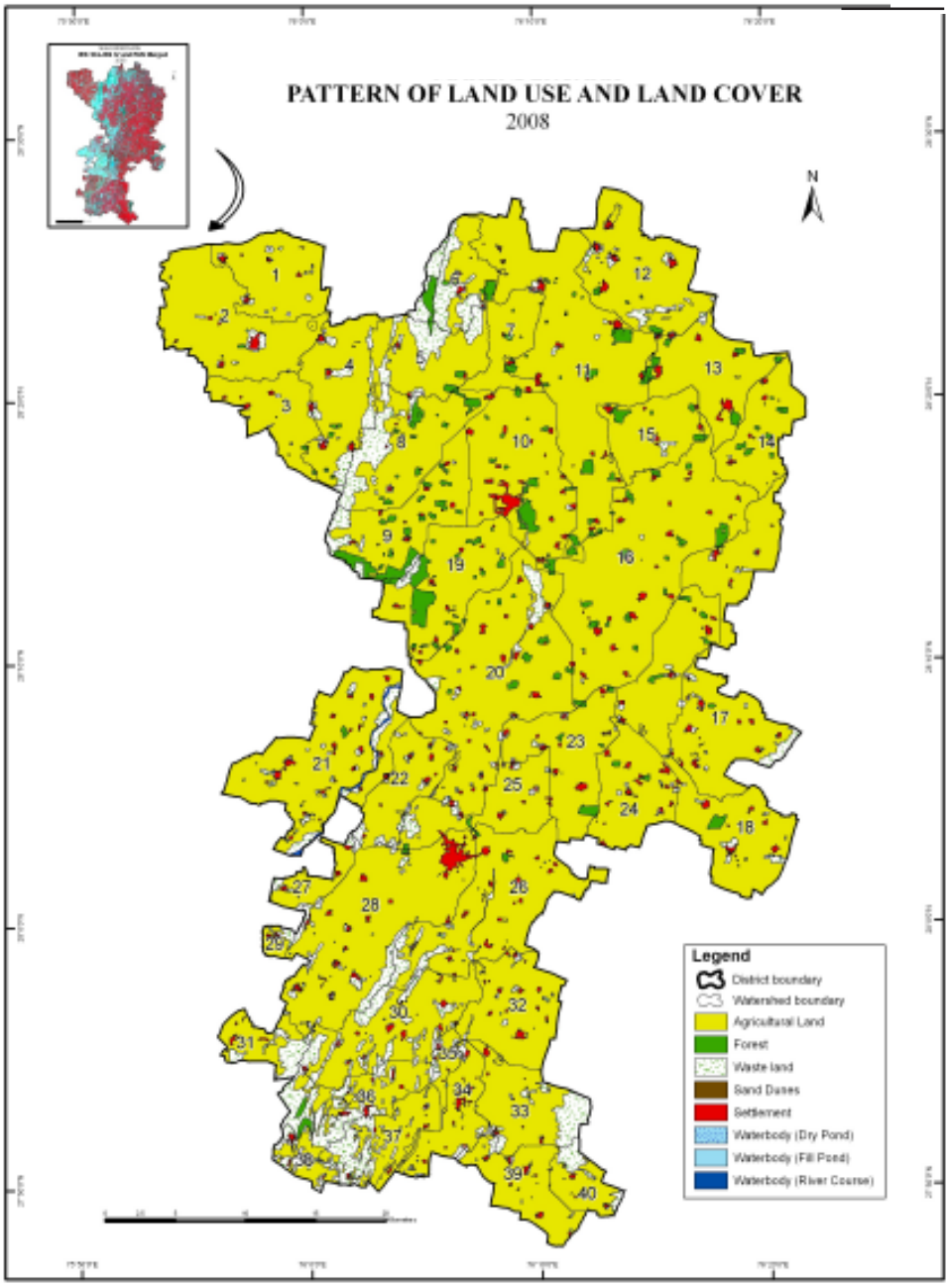

Fig. 4. Mahendergarh - Pattern of landuse and land cover 2008

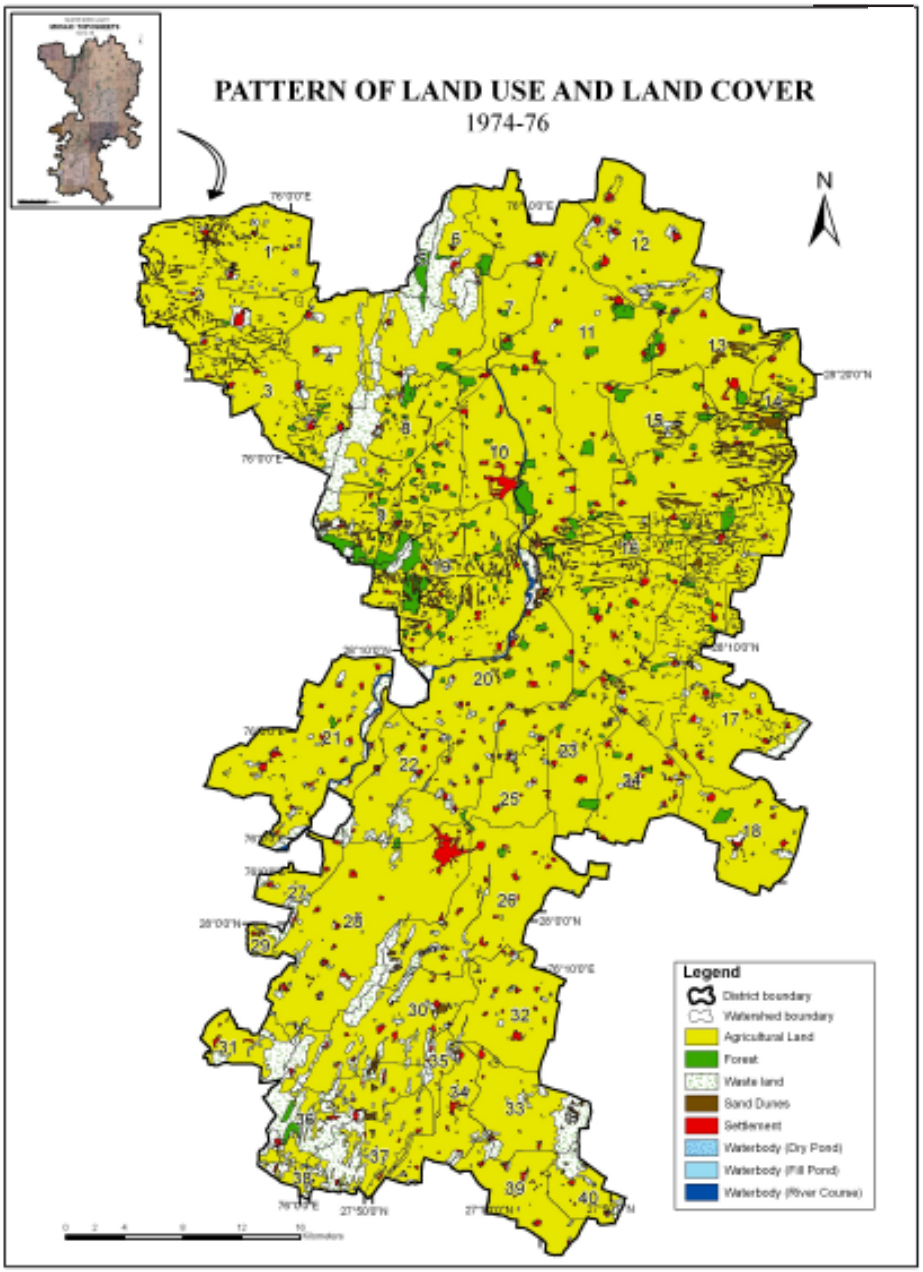

Fig. 5. Mahendergarh - Pattern of landuse and land cover 1974-76

eastern part of study area (numbered as 16) has 5 percent of its land affected by sand dunes and classified as wasteland.

The change in land use pattern over a period of 30 years has also been studied[1]. It shows that agricultural land has increased over a period of time. The area has increased from1629 km² to 1670 km². This is largely due to decline in wasteland (comprising of open scrub and sand dunes). The area under waste land was 10.7 percent in 1976, which has come down to 8.65 percent in 2008. The area under settlement has also increased. The forest cover has remained almost stagnant. There is a decline in area under waterbody or say river course which was 5.11 km². In 2008, it stands as 1.83 km². This is largely due to drying of river channels.

The detailed landuse pattern under different micro-watersheds in 1974-76 has been presented in Table 3 and Figure 5. One can obtain the change in specific watersheds and this pattern may be used as the basis of identifying which micro-watershed needs more attention in terms of treatment and sustainable development. It may be obtained from Table 3 that the same watersheds numbered 5 and 6 in northern part and 36, 38in southern part of the district remain most vulnerable as these have more than 40 percent of their area as waste land (that is, largely under open scrub). The four watersheds have 20 to 40 percent of their area as waste land. These are lying adjacent to the above described watersheds. It may be noted that there is marginal decline in open scrub in micro-watersheds lying in southern region. Area under agricultural land has increased substantially in 14, 16, 19 and 20 micro-watersheds, which lies in a strip east to west across northern portion of the study area.

CONCLUSION

The present study demonstrates the utility of remote sensing and GIS techniques in delineation of micro-watersheds in an arid area. The study involved delineation of 40 micro-watersheds in 2 sub-watersheds of Krishnawati and Dohan rivers lying in Mahendergarh district.

The application of these micro-watersheds has been studied in terms of their existing land use pattern. Different land use classes depict the problems pertaining to the natural resource management in the area. The existence of wasteland in the large area poses serious problem. This study of change in landuse pattern over a period of 30 years revealed that the 3 micro-watersheds lying in north and 3 in southern part of district are more vulnerable in terms of proportion of waste land. Similarly it does reveal that few micro-watersheds lying in eastern part have shown positive change. Hence development based on watershed approach is an ideal way of sustainable development for agriculture and subsequently rural development. This approach is more feasible to ecological balance in the long term.

NOTE

1. It has been attempted for 1974-76 using SOI toposheet.

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