Evaluation and geo-database creation of watersheds in Siwaliks, Haryana

V. S. Arya*, Raj Kumar and R. S. Hooda

Haryana Space Applications Centre (HARSAC), Hisar 125 004, India

An evaluation for the development work done in the two watersheds, viz. Bunga and Dabkauri in Panchkula District, Haryana was carried out for 2004 and 2007. Satellite digital data of LISS-IV sensor for 2004 and merge product of LISS-III and PAN for 2007 was used. The data was interpreted for their land use/land cover classes for both the years. The data shows that there is an increase of 33.93% in crop land area. There is a substantial decrease of 97.84% in agricultural fallow land, i.e. land without scrub and sparse vegetation on hills also decreased during the period. Dense vegetation area, i.e. forest plantations on the hills and in the Piedmont area was increased. It was observed that a total of 33 water harvesting structures were constructed between 2004 and 2007.

Keywords: Evaluation, geo-database, Piedmont, watershed.

REMOTE sensing has become an indispensable scientific tool for mapping and monitoring of natural resources and is frequently used for planning, characterization and management of these resources particularly on watershed basis. Watershed is a geo-hydrological unit and topographical delineated area draining at a common point by a system of streams. Essentially, a watershed is land and water area which contributes runoff to a point; it is a land area that captures rainfall and conveys the overland flow and runoff to an outlet in the main flow channel.

In general, the hilly watershed has problems related to soil and water. The primary problems are flooding, siltation, soil erosion and deforestation because of highly dissected nature of terrain with steep slopes, escarpments, landslide and erosion compounds, and rate of surface runoff in the watershed. Various studies on watershed management through remote sensing have been done. Arya *et al.*[1] prepared various thematic maps of the Ghaggar Watershed Area, which were used to develop land and water resources management plans for sustainable development of the area. Pramod and Manchanda[2] have conducted land use and vegetation change analysis by assessing the area weighted NDVI for major land-use change categories in nine watersheds.

Development of a suitable and effective methodology using state-of-art technologies for evaluating the effectiveness of the watershed development programmes and monitoring their progress have become inevitable. The present study aims at developing and demonstrating such methodology by taking two watersheds as the case study.

As the study area belongs to lower Siwaliks having less clay which render the groundwater recharge though the area receives about 1000 mm rainfall annually, most of this water is lost by surface runoff and only a small part of it infiltrates into the ground. Absence of sufficient number of structures for rainwater harvesting and checking the stream flow results in loss of surface water as runoff. The study aimed at providing an insight into the impact of developmental activities, to create a geo-database in Geographic Information System (GIS) and also provide feedback for the effectiveness of watershed treatment programmes.

Study area

In the present study, two watersheds, viz. Bunga and Dabkauri under rainfed farming in Panchkula District, Haryana were selected for evaluation purpose. These watersheds are located between 30°37′38″–30°41′42″N lat. and 76°56′53″–76°58′42″E long. The total area of these two watersheds is 500 ha each.

Physiography

Physiographically the study area can be divided into two distinct units, viz. Siwalik hills and foothill rolling plain. The Siwalik hills, which have a north-west, south-east disposition, flank the northern boundary of the study area whereas, foothill rolling plain is a long belt of undulating, fairly sloping plain with elevation between 300 and 400 m, adjoining the Siwalik range.

The dominant soils found in the study area are loamy Dystric Haplustepts, loamy Typic Ustorthents, fine Typic Haplustepts, coarse loamy Typic Ustorthents and fine loamy Typic Haplustepts (Haryana Space Applications Centre (HARSAC))[3].

The climate of the district is characterized by a very hot and dry summer, southwest monsoon season and a bracing cold season.

The average annual rainfall in the district is 985.1 mm. About 81% of the annual normal rainfall is received

*For correspondence. (e-mail: aryaharsac@gmail.com)

during June–September whereas about 11% in the winter months of December–February. The temperature increases rapidly from March. May and June are generally the hottest months of the year with the mean daily maximum temperature of about 41°C and the mean daily minimum of about 25–27°C. The natural vegetation is mainly of forest growth. The forests in the Siwalik zone are of the following types: (i) Siwalik chir pine forests; (ii) dry Siwalik sal forests; (iii) northern dry mixed deciduous forests and sub-types and (iv) dry bamboo brakes.

Database and methodology

Indian Remote Sensing (IRS) satellite data from LISS-IV, PAN+LISS-III sensors were analysed for change detection. The details of the satellite data are given in Table 1. The satellite data were geo-referenced by using ground control points (GCPs) and geometric rectification was performed using second order polynomial transformation model. Land use/land cover analysis was done by using hybrid approach. Maps provided by the Department of Agriculture, Haryana were used for digitizing watershed boundaries.

Interpretation of satellite data

Based on the standard image characteristics such as tone, texture pattern, shape, size location and association, visual/digital classification of remotely sensed date using a hybrid approach was carried out and land use/land cover maps were prepared for 2004 and 2007. These maps were put in GIS format and overlaid on one another for change detection. The third map was derived showing the change in the area of various land use/land cover classes in the study area.

Ground truth

Ground truth was carried out on the selected locations of ambiguous features. The pre-field maps were modified by incorporating field observations. After due corrections, attributes were attached and final digital maps were prepared. Locations of the soil and water conservation structures were taken in terms of latitudes and longitudes using the handheld Global Positioning System (GPS). Accuracy of the GPS observations was 10 m.

Results and discussion

Temporal land use/land cover analysis was performed to assess the land utilization pattern, wasteland reclamation and sustainable growth of the watersheds. The database for these watersheds was also prepared. A significant increase in cropped land in both the watersheds and partial transformation of fallow and waste lands into cultivated lands was observed (Tables 2 and 3). The watersheds were evaluated based on changes in the areal extent of their land use/land cover categories between 2004 and 2007 (Figures 1 and 2). The soil and water conservation structures constructed in these watersheds during this period were also demarcated in the map. The description of the change in each category found in these watersheds is given below.

Bunga Watershed

The land use/land cover categories were identified as cropped land, agriculture fallow, land with scrub, land

Table 1. Details of the satellite data used for both the watersheds

Satellite	Sensor	Path	Row	Date of pass
IRS P6	LISS-IV	202	055	13 March 2004
IRS P5 + IRS P6	PAN + LISS-III	521, 95	257, 49	9 December 2006 and 26 February 2007

Table 2. Areal extent of various categories during 2004–2007 in Bunga Watershed

Category	Area (ha) 2004	Area (ha) 2007	% Change
Settlement	10.24	14.58	+42.38
Cropped land	122.91	164.62	+33.93
Agriculture fallow	39.73	0.86	–97.83
Land with scrub	24.75	24.25	–02.02
Land without scrub	21.87	15.03	–31.27
Dense vegetation	162.87	188.67	+15.84
Sparse vegetation	82.50	55.82	–32.33
Water course	29.29	29.66	+01.26
Water body/ponds	6.78	07.45	+09.88

Table 3. Location of structures in Bunga Watershed

Structure	Longitude	Latitude
Earthen gully plugging	76°57′06.186″	30°39′48.492″
Silt deduction dam	76°57′03.384″	30°39′46.806″
Earthen gully plugging	76°57′42.750″	30°39′53.112″
Pond	76°57′44.718″	30°39′59.178″
Earthen gully plugging	76°57′42.660″	30°40′05.598″
Earthen gully plugging	76°57′47.184″	30°40′05.838″
Old spillway and pond	76°57′52.668″	30°40′05.442″
Bunga dam	76°57′58.986″	30°40′08.874″
Cement massionary structure	76°57′54.642″	30°39′51.894″
Cement massionary structure	76°57′53.430″	30°39′47.718″
Cement massionary structure	76°57′51.624″	30°39′46.692″
Earthen gully plugging	76°57′23.892″	30°40′02.436″
Earthen gully plugging	76°57′25.422″	30°39′53.262″
Earthen gully plugging	76°57′26.411″	30°39′50.211″
Earthen gully plugging	76°57′22.356″	30°39′54.210″

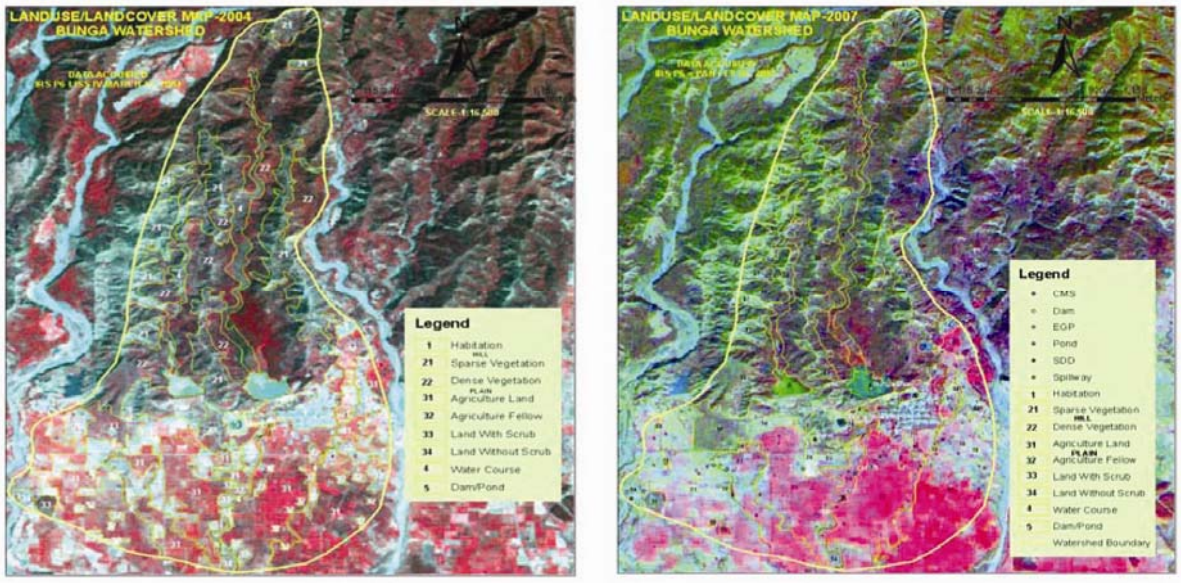

Figure 1. Land use/land cover maps of Bunga Watershed for 2004 and 2007.

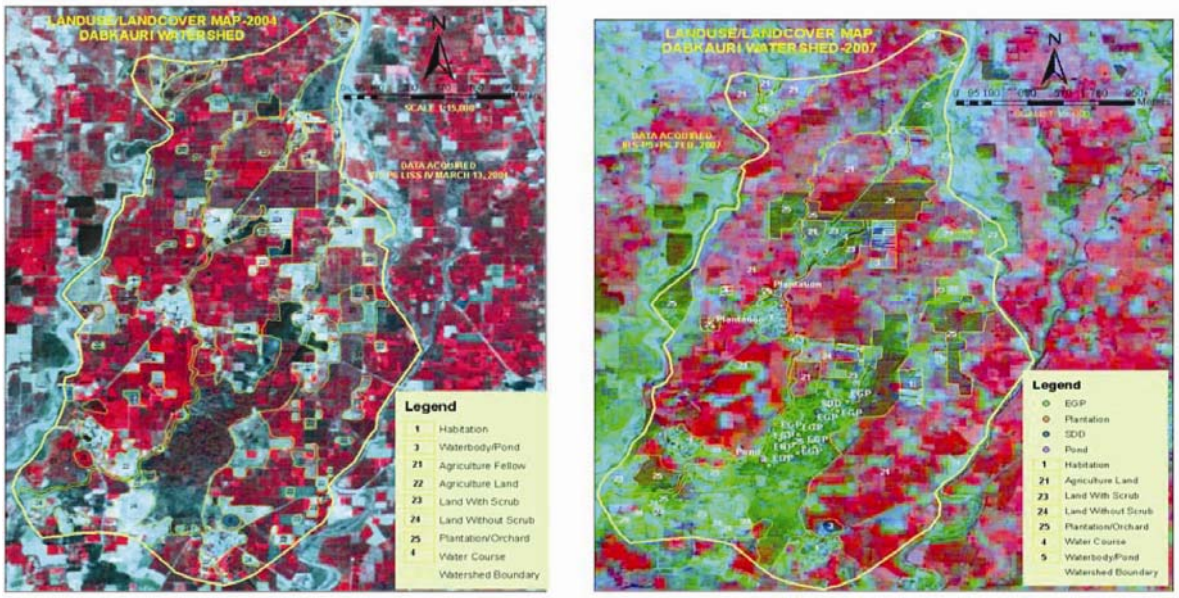

Figure 2. Land use/land cover maps of Dabkauri Watershed for 2004 and 2007.

without scrub, dense vegetation, sparse vegetation, water course, water bodies/ponds and settlements. The areal extent of these categories is given in Table 2. A brief description of various classes is as follows.

Cropped land: These are the areas used by farmers for growing crops. The area falls in the Piedmont zone. The study showed that the cropped land in the watershed increased by 33.93% from 122.91 ha in 2004 to 164.62 ha in 2007. Interviews with the farmers of the area indicated that the yield per ha has also increased after watershed activities.

Agriculture fallow: This is the agriculture land but left uncultivated. The area under this category was 39.73 ha during 2004 which reduced to 0.86 ha in 2007 indicating a drastic reduction of 97.83%. The data shows that almost whole of the fallow area is converted into cropped lands.

Land with scrub: This is the land generally prone to deterioration due to soil erosion and has scanty vegetation cover. Such land occupied relatively high topographic locations. The area under this category in 2004 was 24.75 ha which remained almost the same in 2007 also, i.e. 24.25 ha.

Land without scrub: These are the scrub lands with relatively high topographic locations but without vegetation cover. The satellite data for 2004 shows that the area under this category was 21.87 ha which was reduced to 15.03 ha in 2007, indicating a decline of 31.27%.

Dense vegetation: This class is found on the Siwalik hills. Mostly the area is under forest department where plantation has been done by the department. This class is also found in the Piedmont zone on the farmers' fields where the plantation is done either by the farmer or by Department of Agriculture. The area under this category in 2004 was 162.87 ha which increased to 188.67 ha in 2007, showing increase of 15.84%.

Sparse vegetation: This category is also found in the hills. The area is covered with natural grasses mostly with *Lantana* sp. At some places the plantation has been done by the forest department but the canopy cover is very less. In the satellite data of 2004, the area under this category was 82.50 ha which is reduced to 55.82 ha in 2007 showing a decrease of 32.33%.

Water courses: The area under this category is covered by the natural drains passing through the watershed area. These are the seasonal drains that flow only during monsoon season. The area under this category in the both years is almost the same, i.e. 29.28 and 29.65 ha.

Water bodies/ponds: The area under this class during 2004 was 6.78 ha which increased to 7.45 ha in 2007. The increase in the area under this category is due to the increase in the number of water bodies/ponds in the watershed.

Soil and water conservation structures: It was observed that a total of 15 soil and water conservation structures were constructed between 2004 and 2007 (Table 3). These are earthen gully plugging, silt deduction dam, cement massionary structures, dams and ponds. These structures were constructed on the right locations and successfully intercepted surface runoff and recharged the groundwater as a result crop yield per ha was increased. The surface water availability has also increased and is being used for daily purposes.

Dabkauri Watershed

The Dabkauri Watershed is located immediately below the Bunga Watershed area. Total area lies in the Piedmont zone of Siwalik hills and cover an area of 500 ha. The land use/land cover categories were identified as cropped land, agriculture fallow, land with scrub, land without scrub, plantations/orchards, water courses, water bodies/ponds and settlements. The areal extent of these categories is given in Table 4. A brief description of various classes is as follows.

Cropped land: The satellite data of 2004 shows that cropped land in the watershed was 263.73 ha and it changed to 328.07 ha in 2007 indicating a 24.62% increase. This increase may be due to decrease in the area of 'land without scrub' and conversion of total area of 'agriculture fallow' class into this category. According to the discussions with the farmers, the yield per ha has also increased after watershed activities.

Agriculture fallow: The area in 2004 was 34.58 ha but no fallow area was seen in 2007. It shows that almost whole of the fallow area is converted into cropped lands.

Land with scrub: The area in 2004 was 49.01 ha which reduced to 46.26 ha in 2007, indicating a 5.61% change.

Land without scrub: The satellite data for 2004 shows that the area was 59.32 ha which had reduced to 7.57 ha in 2007. The drastic reduction of 87.24% in the area and increase in cropped lands shows that the maximum area is shifted to cropped lands.

Plantations/orchards: This class is found on the eastern side of the watershed. Mostly the area is under forest department where plantation has been done by the department. At some places, this class is found on the farmers' fields also where the plantation is done by themselves. The area in 2004 was 64.19 ha which had increased to 88.26 ha in 2007. This indicated an improvement of 37.50%.

Water course: The area in 2004 was 11.39 ha which reduced to 9.84 ha in 2007. It shows that some area was reclaimed and put under plantations.

Water bodies/ponds: The satellite data showed that the area in 2004 was 2.67 ha and it was 2.66 ha in 2007, indicating no change.

Table 4. Areal extent of various categories during 2004–2007 in Dabkauri Watershed area

Category	Area (ha)		% Change
	2004	2007	
Settlement	15.10	16.76	+10.99
Cropped land	263.73	328.67	+24.62
Agriculture fallow	34.58	–	–100.00
Land with scrub	49.01	46.26	–5.61
Land without scrub	59.32	7.57	–87.24
Plantation/orchards	64.19	88.26	+37.50
Water course	11.39	9.84	–13.60
Ponds	2.67	2.66	–0.37

Table 5. Location of structures in Dabkauri Watershed

Structure	Longitude	Latitude
Silt deduction dam	76°57′23.724″	30°37′59.706″
Earthen gully plugging	76°58′01.932″	30°38′22.368″
Earthen gully plugging	76°57′59.976″	30°38′20.436″
Earthen gully plugging	76°57′58.422″	30°38′21.480″
Silt deduction dam	76°57′56.040″	30°38′20.382″
Earthen gully plugging	76°57′55.224″	30°38′17.568″
Earthen gully plugging	76°57′54.984″	30°38′14.160″
Earthen gully plugging	76°57′55.320″	30°38′13.038″
Earthen gully plugging	76°57′53.142″	30°38′13.056″
Silt deduction dam	76°57′51.882″	30°38′11.856″
Earthen gully plugging	76°57′49.374″	30°38′11.088″
Earthen gully plugging	76°57′46.098″	30°38′09.252″
Pond	76°57′44.256″	30°38′09.816″
Earthen gully plugging	76°57′49.164″	30°38′13.140″
Earthen gully plugging	76°57′48.510″	30°38′14.610″
Earthen gully plugging	76° 57′49.962″	30°38′16.068″

Soil and water conservation structures: It was observed that a total of 16 soil and water conservation structures were constructed between 2004 and 2007 (Table 5). These are earthen gully plugging, silt deduction dam and ponds. These structures have successfully intercepted surface runoff and recharged the groundwater as a result crop yield per ha has increased. The surface water availability in the area has also increased which is being used for daily purposes.

Conclusions

The present study was done to analyse the impact of watershed treatment programme in two watersheds, viz. Bunga and Dabkauri in Panchkula District of Haryana. The land use/land cover change analysis were performed during 2004 and 2007. The following conclusions could be derived from the study.

(1) High-resolution satellite data can be used to identify soil and water conservation structures and to study changes in the land use of the watershed to assess the impact of watershed treatment programme.

(2) The land use/land cover analysis reveals that there is substantial improvement in the cropped area in both the watersheds. During the period, fallow and wastelands decreased substantially. The decrease in fallow lands was 97.84% in Bunga and 100% in Dabkauri, whereas the decrease in wastelands was 15.74% and 50.03% in Bunga and Dabkauri respectively.

(3) The increase in cropped area and dense vegetation/plantations may be due to decrease in fallow and wastelands in both the watersheds.

(4) The structures constructed by the watershed authorities have been successful in intercepting surface runoff and recharging ground water.

(5) Crop yields per ha were also increased due to the increase in availability of surface water as a result of construction of structures.

(6) The area under agriculture fallow and wastelands can also be brought under cropped lands and plantations.

(7) For analysing the overall impact of watershed treatment programme, other parameters on socio-economic impacts should also be included.

1. Arya, V. S. *et al.*, Land resources development action plan using remote sensing and GIS: a case study in Ghaggar Watershed. *International Archives of Photogrammetry, Remote Sensing and Spatial Information Science (IAPRS&SIS)*, 2002, **34**, 665–670.
2. Pramod Kumar and Manchanda, M. L., Monitoring watersheds: Remote sensing approach – case studies from UP, India. Proceedings of International Conference on Land Resources Management for Food, Employment and Environmental Security (ICLRM), 9–13 November 2000, Soil Conservation Society of India, New Delhi, pp. 573–584.
3. HARSAC Report, Soil resources of Panchkula District, 2007.

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