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AGRICULTURAL PLANNING AND SUSTAINABLE DEVELOPMENT OF UNGAUGED WATERSHED AREA USING REMOTE SENSING AND GIS

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ABSTRACT
The existing system of water resources information generation is tedious, time consuming and difficult for remote and inaccessible areas. Remote sensing is fast emerging as an important and cost effective in updating the existing water resources information and developing a sound database for proper resource planning. The sub watershed (5G1C5e) of 16940 ha was identified and considered for the study purpose. The thematic maps were prepared using the Remote Sensing images and GIS software. The Soil Conservation Service Curve Number (CN) method is used for computing the runoff. The impacts of the measures were assessed by computing runoff under alternative land use and management practices. The percentage area under single crop and double crop were found as 71.81 and 18.02% respectively. The existing single crop pattern in soil having shallow (40.75%) and moderately (36.02%) buried pediplain were recommended to cover under agro-horticulture and double cropping respectively. It was observed that the annual mean runoff yield is decreased by 11.76 % of the values at pre-conservation.

KEYWORDS: Watershed development, crop planning, Remote sensing & GIS

INTRODUCTION
A watershed can be defined as the area of land that drains to a particular point along a stream. Each stream has its own watershed. It is the area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community. Rapid increase in population, urbanization, over utilization of ground water resources, large Construction, etc., have resulted in ever increasing demand on land and water, and caused enormous degradation of environment and forest, loss of productive soils, depletion, reservoirs and ground water resources. Therefore, conservation of soil and water resources is most important

Estimation of runoff is possible by the identification of parameters such as land use/land cover, physiography, geomorphology, soils, hydrology, etc. Some of these phenomena are dynamic phenomena, which change from one growth stage to another, season-to-season, year-to-year and with agro-climatic regions. Carpenter *et al.* (1999) studied national threshold runoff estimation utilizing GIS in support of operational flash flood warning systems. In this work, Geographic Information Systems (GIS) and digital terrain elevation databases were used to develop a national system for determining threshold runoff. Soil and Water Conservation measures have been long practiced to protect the productive lands. These measures are suggested based on terrain characteristics like land use, soils, slope, hydro-geomorphology, etc. Remote Sensing and GIS techniques have been used recently to arrive at cost-effective plans for conservation and development measures for watersheds. In our country, the existing system of water resources information generation is tedious, time consuming and difficult for remote and inaccessible areas. Remote sensing technology integrated with conventional methods is fast emerging as an important and cost effective tool in the appraisal of natural resources. Remote sensing would be of great use in updating the existing water resources information and developing a sound database for proper resource planning. GIS is a powerful tool with the unique capability for storing, manipulating, retrieving of both spatial and non-spatial data to perform simple/complex analysis of the spatial data in desired procedural way. Zade *et al.* (2005) evaluated spatial curve number map for major basins of India using remote sensing and GIS and stated that Curve Number (CN) was the most common method used to estimate run off. The manual survey is very cumbersome, time consuming and costly. Therefore, the present study was mainly aimed for planning and management of watershed area for sustainable development using remote sensing and GIS.

METHODOLOGY
Location
The study area forms the part of the Bhesan and Visavadar talukas of Junagadh district of Gujarat state. Study area (sub-watershed 5G1C5e) has 23 micro watersheds. Three principle rivers Uben, Ozat and Hiran drain into Junagadh district. Agricultural activities are largely limited to Kharif season though some agricultural areas are irrigated through wells and bore wells. The study area is lying between 21^0 23” 15.39’ and 21^0 33” 35.27’ north latitude, and 70^0 38” 16.25’ and $70^0$52”24.55’ east longitude, covering a total area of 16,940 ha. The study area has three pronounced seasons, the monsoon season of mid June to early October; the dry winter season, which follows

through until February and the hot dry season from March to mid-June. The area is characterized by the high variability in the rainfall from 209 to 3176 mm. It is characterized by erratic rainfall pattern and the average annual rainfall is 824.7 mm (1959-2000).

DATA COLLECTION

Spatial data

Satellite data: The false colour composites (FCC) of IRS-1C PAN + LISS-III merged geocoded products on 1:25,000 scale are used for classification of various themes. The IRS-1C PAN+LISS III (merged data) image of the study area is shown in Fig 1.

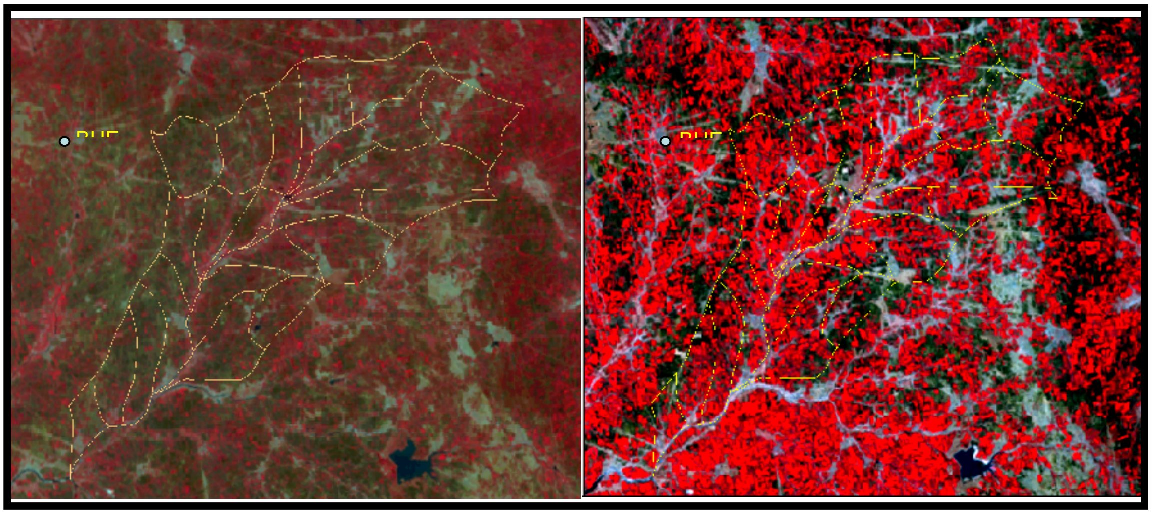

Fig 1. IRS-1C PAN + LISS III (merged data) image of the study area

Collateral data: Study area (sub-watershed) has been delineated from Survey of India (SOI) topographic sheet. The sheet number 41-K/10, 41-K/11, 41-K/14 and 41-K/15 of 1:50,000 scale were used in the study. Soil map and report prepared by National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) have been used in the study.

Non-spatial data

Rainfall data: Daily hourly rainfall data of the rain gauge stations at head quarters of Bhesan, Junagadh, Munjiyasar (near to Bagsara) and Visavadar for 10 years in mm were collected from State Water Data Center (SWDC); Gandhinagar has been used in the study.

GENERATION OF THEMATIC MAP

All the maps are digitized in the *ARCVIEW* module of *ARC/INFO* Geographic Information System (GIS).

Study area preparation

The entire study area is covered in Survey of India (SOI) topographic map on 1:50000 scale. The sub-watershed has a total area of approximately 16,940 ha. This map was then superimposed on the satellite data products and matched with the features present on the satellite imagery for the interpretation purpose. This map is used as the base map throughout the study.

Drainage map

Drainage map of the study area has been delineated using satellite imagery. The drainage map has been later used to delineate micro-watershed boundaries. The same concepts are used while delineating sub-watershed boundaries as in the case of study area map (base map) preparation. The surface water bodies have been studied and delineated using satellite imagery.

Land use/land cover map

To evaluate the land use/land cover condition of the study area satellite imagery is used. The interpretation and correlation of imagery with objects involved the comparison of spectral response of each type of objects with tinge characteristics. Mono-scopic visual interpretation of IRS-1C LISS III + PAN merged geocoded false colour composite (FCC) on 1:25,000 scale for the date of 5/1/2005 and 19/10/2005 are done for identification of different land use/land cover classes. The interpreted details are checked on ground to verify the interpretation and doubtful areas. Based on the ground verification, boundaries of the different land use/land cover units are finalized. Various land use categories present in the study area are described below:

Agricultural Land

This class of land is broadly defined as the land, which is used primarily for production of field crops. Groundnut, cotton, mole, wheat, etc. are the major crops grown in the study area. Agricultural land is further classified into (a) Double cropped (Kharif + Rabi) and (b) Single cropped (Kharif).

Waste Land

Wasteland is classified into (a) Wasteland with scrub and (b) Wasteland without scrub. Wasteland with scrub is an area with scant vegetation. This class of land was identified mainly on the basis of light pink to greenish blue tone. Wasteland without scrub in the study area is an area with out scant vegetation. This class of land was identified as whitish tone.

Patel and Joshi (2001) dealt with hydro-geo-morphological mapping and land use classification was carried out in part of Baran district, Rajasthan with the help of IRS-IC LISS III data.

HYDROGEOMORPHOLOGICAL MAP

Using standard visual interpretation techniques and satellite images of IRS 1C LISS III+PAN merged (FCC) geocoded products of 1:25,000 scale. There are mapped eight different hydrogeomorphological units.

Estimation of Runoff

The method established by Soil Conservation Service (SCS) (U.S. Conservation Service, 1972) is used to study the hydrologic response of the watershed to precipitation in order to prioritize micro-watersheds for adopting suitable water conservation measures. This method is used to estimate direct runoff volume from the rainfall depths. This method takes into account the parameters characterizing a watershed such as land use, hydrological soil cover, and Antecedent Moisture Condition (AMC) for predicting yield from the watershed.

$I_a = 0.1S$ for AMC - II, and AMC-III

$$Q = \frac{(P - 0.1S)^2}{P + 0.9S} \qquad (1)$$

$I_a = 0.3S$ for AMC - I

$$Q = \frac{(P - 0.3S)^2}{P + 0.7S} \qquad (2)$$

In eq. (2) the unknown Potential Maximum Retention (*S*) can be evaluated as,

$$S = \frac{25400}{CN} - 254 \qquad (3)$$

Where, *S* in mm, and CN = Runoff Curve Number which represents the combine effect of soil, land use, agricultural land treatment class, hydrologic condition and antecedent soil moisture.

Calculation of Runoff Yield

The runoff yield is estimated using the following equation:

$$Yield\ (\%) = \frac{\text{Cumulative Runoff}}{\text{Cumulative Rainfall}}\ X\ 100$$

Generation of Action Plans for Soil and Water Conservation

The procedure adopted for the generation of action plans was the same as that used by the Integrated Mission for Sustainable Development Project (IMSD 1995). Different thematic maps generated were overlaid in a GIS environment to produce composite land development units (CLDU). Each CLDU was analyzed individually to study the problems in that area and criteria-based actions were suggested for soil and water conservation.

Post-Conservation Runoff Scenario

Runoff for the post-conservation scenario was estimated with the recommended new land use and management practices. The runoff under recommended measures was computed again with modified curve numbers CN (Table-1) after integrating the land resources development plan with the hydrologic soil group map.

Table -1. Curve Numbers (CN) adopted for AMC II, post-conservation scenario.

S.No	Suggested land use	Curve Numbers for hydro soil group	
		B	C
1	Double crop	75	82
2	Agro-horticulture	78	85
3	Silvipasture	59	75
4	Prosophis	58	72
5	Habitation	86	91
6	Water bodies	95	95

RESULTS AND DISCUSSION

1. Generation of thematic map

Drainage map

Drainage is drawn from satellite imagery of 1:25,000 scales. Micro-watershed boundaries are delineated using drainage and surface water body map. 23 micro-watersheds are delineated ranging from 366.62 to 1332.51 ha. Drainage map with the details of water bodies is shown in Fig 2.

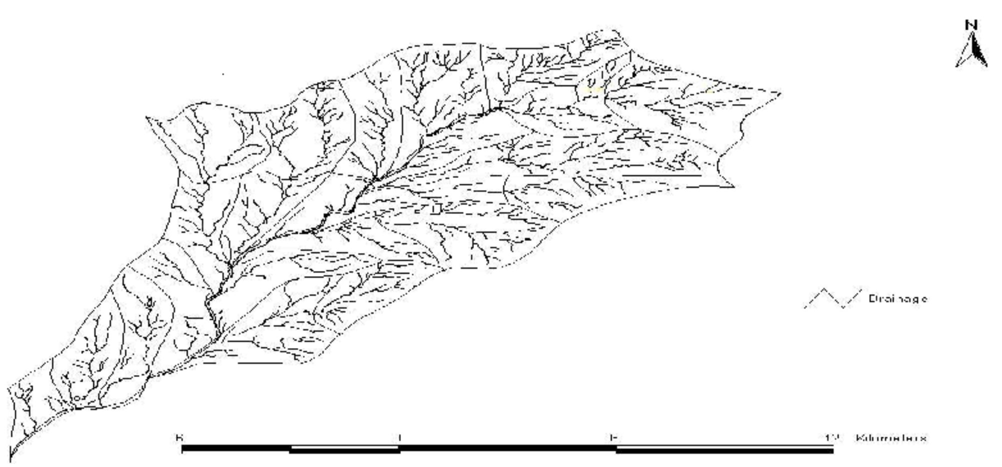

Fig 2 Drainage map

Land use/land cover map

It was found that river Ozat is flowing in the middle portion of the watershed. About 11.37 % areas are occupied by double crop which is largely lying in areas where irrigation facilities are available. All most portions (i.e. 78.46%) of the watershed are occupied by single cropped area. Wastelands occupied about 7.61% areas and are found scattered all over the watershed. Water bodies scattered in the upper portion are found to be small. The land use/land cover map is shown in Fig 3.

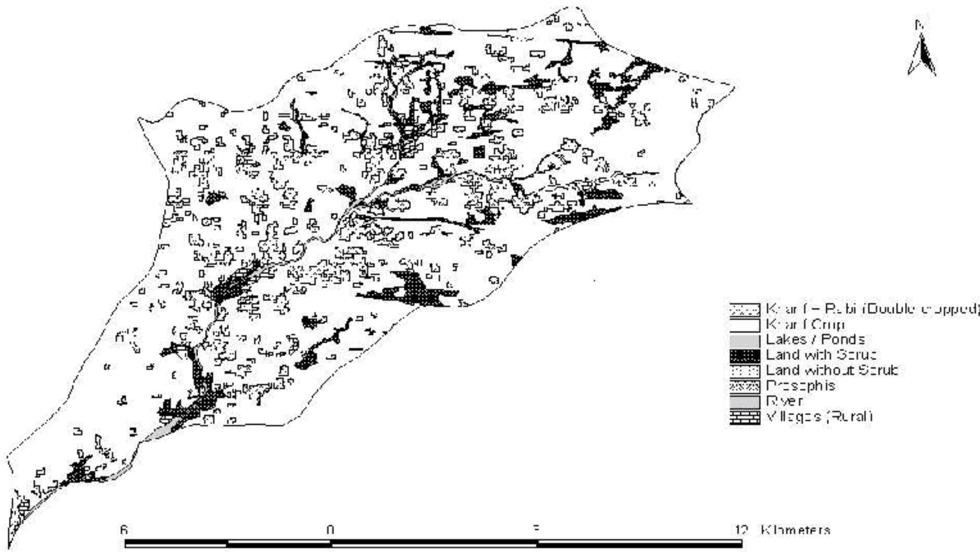

Fig 3 Land use/land cover map

Hydrogeomorphological map

The geomorphic unit, Buried pediplain (shallow) is found largely through all over the sub-watershed which occupied 13686.18 ha area. Pediment occupied the area about 1583.85 ha, which is scattered all over. About 684.64 ha area is occupied by buried pediplain (medium) and it is found in the middle portion of south in large extent. Only 24.46 ha area is occupied by Flood plain. The hydrogeomorphological map is shown in Fig 4.

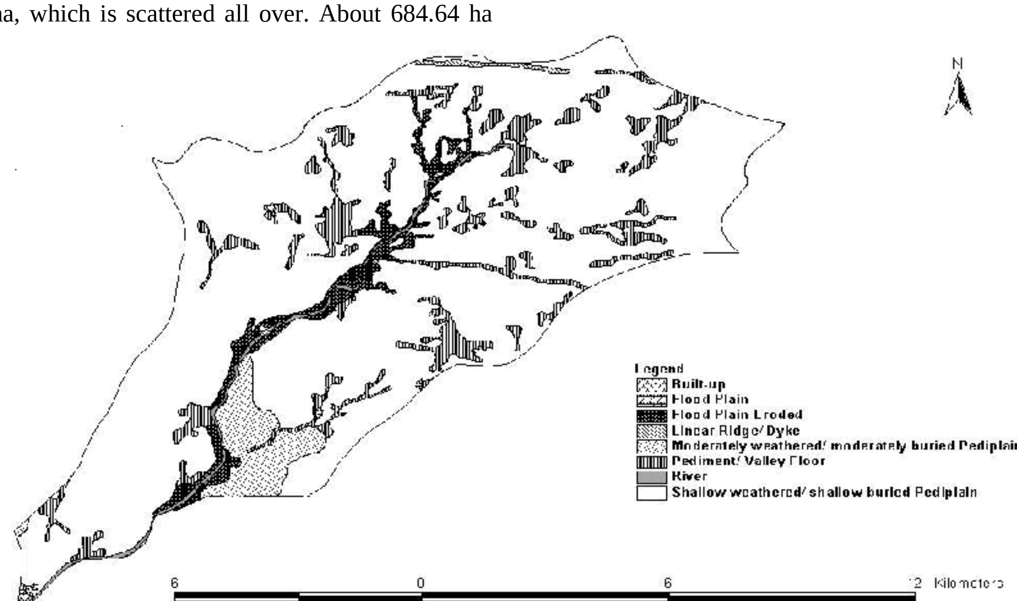

Fig 4 Hydrogeomorphological map

Preparation of modified land use/land cover map

In the present study an attempt has been made to combine both the data sets in order to arrive at more realistic runoff estimates. After ground study using cropping pattern map and crop calendars, totally 4 crops (groundnut, cotton, wheat and cumin) were identified and their spatial distribution was carefully studied. Some of these crops present in small quantities in limited areas. Accordingly, the agricultural class (cropped area) of land use/land cover map based on satellite imagery is reclassified, and a modified land use/land cover map is readied for analysis. The modified land use/land cover used for resource modeling is shown in Fig 5. The areal distribution of different land use/land cover classes is given in Table 2.

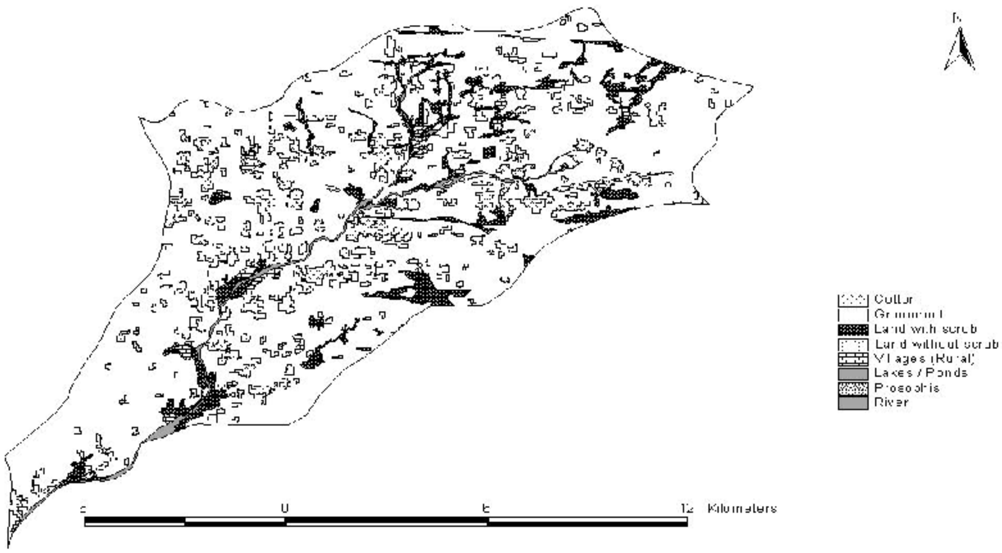

Fig 5 Modified land use/land cover map

Table 2. Areal extents of modified land use/land cover

Sr. No.	Level-I	Level-II	Area (ha)	% of Extent
1	Agriculture	Double Crop	12164.32	71.81
		Single Crop	3052.91	18.02
2	Waste Land	Land With Scrub	1205.55	7.12
		Land Without Scrub	83.03	0.49
3	Habitation	Urban/Rural	204.97	1.21
4	Water Bodies	River	224.20	1.32
		Reservoir/Stream	1.11	0.01
5	Others	Prosophis	4.01	0.02

Generation of Action Plans for Soil and Water Conservation

The procedure adopted for the generation of action plans was the same as that used by the Integrated Mission for Sustainable Development Project (IMSD 1995). Different thematic maps generated were overlaid in a GIS environment to produce composite land development units (CLDU). Each CLDU was analyzed individually to study the problems in that area and criteria-based actions were suggested for soil and water conservation.

Composite Land Development Units (CLDU)

The composite land development unit (CLDU) was generated by overlaying land use map, hydrogeomorphology map, slope map and soil map. The ground water prospects was derived from hydrogeomorphology depending upon the ground water potential in different geomorphic units. The most of the area (about 84.83%) of the total watershed area are having the moderate to poor groundwater. Table 3 gives the areal extent of ground water prospects in the study area.

Table 3 Areal extent of ground water prospective zones

Sr. No.	Ground water prospects	Area (ha)	% of Extent
1	Built-up	46.37	0.27
2	Good	709.09	4.19
3	Moderate to Poor	14369.56	84.83
4	Poor	1583.85	9.35
5	Poor to Nil	57.01	0.34
6	River	174.23	1.03

Recommendations for developmental measures

In areas where crop is grown in both Kharif and Rabi seasons, land use is retained as same suggesting, better agronomic and irrigation practices. Single cropped areas having good ground water prospects and moderately deep soils have been suggested for double cropping with suitable ground water recharge measure. Agro-horticulture is suggested in single cropped areas with moderate ground water prospects. This multiple land use practice is necessary to maintain balance between livestock raising and grazing. Wasteland having poor ground water prospects, and located on pediplain has been suggested for silvipasture. Table 4 shows areal statistics of suggested land use.

Table 4 Areal statistics of suggested land use

Sr. No.	Existing land use	Suggested land use	Area (%)	% of Extent
1	Waste land with/without scrub	Silvipasture	396.56	2.34
2	Single crop	Agro- horticulture	6903.82	40.75
3	Single crop	Double crop	6102.04	36.02
4	Double crop	No action	3103.41	18.32
5	Habitation	No action	204.97	1.21
6	River	No action	224.20	1.32
	Water bodies		1.11	0.01
7	Prosophis	No action	4.01	0.02

Comparison of runoff yield of pre and post conservation scenario

After having estimated the annual yield for all the micro-watersheds for 10 years period, mean annual yield for each micro-watershed was calculated. It is observed that the annual mean yield for the entire watershed is decreased from 42.29 % (Pre conservation) to 30.53% (Post conservation) i.e. there was decrease of 11.76 %.

CONCLUSIONS

The sub watershed of 16940 ha comprising of 23 micro watersheds falling in Bhesan and Visavadar talukas of Junagadh district in Gujarat was identified and considered for the study purpose. The areas of micro-watersheds are ranging from 366.62 to 1332.51 ha. The thematic maps viz. drainage map, Land use/ Land cover and hydrogeomorphological map were prepared using the Remote Sensing images dated 05/01/2005 and 19/10/2005, soil maps and reports prepared by NBSS & LUP. The percentage area under single crop and double crop were found as 71.81 and 18.02% respectively. It was found that major part (84.83 %) of the sub watershed is having the moderate to poor groundwater prospects. The existing single crop pattern in soil having hydrogeomorphology of shallow buried pediplain (40.75%) and moderately buried pediplain (36.02%) were recommended to cover under agro horticulture and double cropping respectively. It was observed that the annual mean yield for the entire watershed is decreased by 11.76 % of the values at pre-conservation.

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