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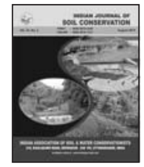

Cadastral level agricultural resources planning through remote sensing and GIS techniques

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ABSTRACT

An attempt has been made for agricultural resources planning of the village Jalondar (District Junagadh, Gujarat) using Remote Sensing and GIS Techniques. Out of five micro-watersheds in the village area, a micro-watershed having an area of 602.83 ha was selected for preparing the action plan. Maps on various themes such as land use/land cover, soil texture, slope and drainage pattern were prepared using remote sensing image (IRS P6 LISS IV image) and Arc View and ENVI softwares. Arc View software was used for preparation of thematic maps while the Environment for Visualizing Images (ENVI) software was used for registration and superimposition of cadastral map with thematic maps. Rational method was used to estimate the peak runoff rate while curve number method was used to estimate the runoff volume. Information available from various thematic maps was used for designing various soil and water conservation measures such as contour bunding, staggered contour trenches, continuous contour trenches, loose rock dams and water harvesting structures. Annual water storage capacities of suggested structures were estimated at 69.89, 14.10, 9.45, 1.48 and 6.78 ha-m, respectively. The suggested conservation measures fulfill the existing water resource gap (167.76 mm) of watershed at 60% probability of rainfall.

1. INTRODUCTION

The natural resources of a country are its most sacred endowment. It is a base on which all life depends and in most countries of the world, it is the life support system. Land and water are the important natural resources on the earth as they play a vital role in agricultural development and watershed planning. The major objective of the watershed development programme is to increase/stabilize production of crops in rainfed areas by introduction of improved soil and moisture conservation measures, animal husbandry and afforestation. Development plans for optimal management of natural resources of a watershed on sustainable basis require reliable, up to date spatial information of physical/terrain parameters, climatic and socio-economic profile of the area. The success of planning for developmental activities depends on the quality and quantity of information available on both natural and socio-economic resources (Patel and Rajput, 2001; Singhal, 2001; Kannan *et al.*, 2003). Watershed development and management programmes are being implemented by various Government agencies and NGOs nowadays. These agencies collect information by conventional survey methods for making action plan of watershed programmes. The process of making action plan is cumbersome, time-consuming and costly. Sometimes due to lack of appropriate information, the planning of watershed management is improper. The application of satellite remote sensing for land use surveys and mapping is gaining importance largely because of its ability to provide rapid and reliable data within a given time frame (Kar, 2000). In the present study an attempt has been made for cadastral level watershed planning using remote sensing and GIS techniques.

2. MATERIALS AND METHODS

Location

The village Jalondar (District Junagadh, Gujarat) selected for study, lies between 70^{0}27'1.18” and 70^{0}30'13.19” East longitude and 21^{0}11'45.31” and 21^{0}8'41.47” North latitude of the semi arid climatic zone. The location map of village Jalondar is shown in Fig. 1.

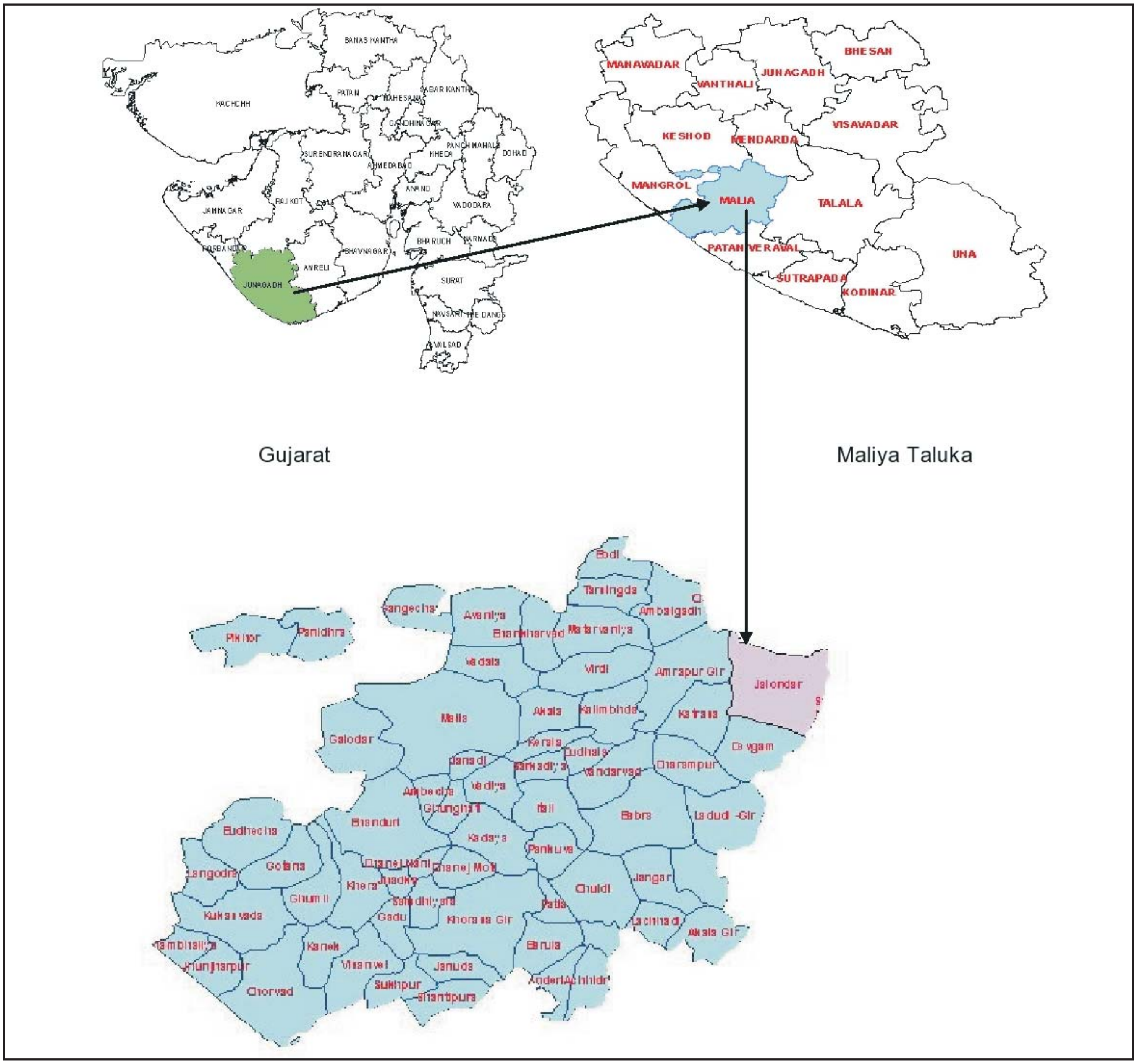

Fig. 1. Location map of village Jalondar

Data Collection

Participatory Rural Appraisal (PRA) technique was used for collecting information of the village such as socio-economic, occupational, geographical, climatic *etc.* from different categories of farmers. Information, which includes natural resources, roads, residential area, industrial area, streams, river, existing structures etc. was collected and superimposed on the cadastral map (Revenue Department, Junagadh District, Gujarat).

Socio-Economic Information

Out of 320 families (1740 persons) living in the village, 256 families were cultivators, 38 families were agricultural labours, 20 families depended on animal husbandry and forestry and 6 families were involved either in service or looking after their own business or mining. Animal resources of villagers comprised of 349 cows, 666 buffaloes and 342 bullocks.

Land Use Pattern

As per Census 1991, total cultivated land accounts to 76% of total revenue land (1611.63 ha) of the village while total culturable wasteland and area not available for cultivation covers 12.27 and 11.73%, respectively.

Cropping Pattern

The total cropped area of the village was 1224.93 ha. The entire village was mainly characterized with mono cropping system. The cropping pattern of the village consists of crops like groundnut (90%), cotton (5%), castor (2%), pigeon pea (2%), black gram (1%) in *kharif* season and wheat (60%), cotton and castor in *rabi* season under irrigated conditions. In summer season, maize and jowar (5%) were grown for fodder purpose only. The major crop sequence followed in the village was groundnut-wheat, cotton-jowar/maize.

Selection of Micro-Watershed

In the modern concept of planning and development of degraded natural resources, the micro-watershed as a geo-physical unit has been accepted as a rational unit for planning and implementation of programme (Kumar, 1999 and Ramchandran *et al.,* 2001).

There are mainly five micro-watersheds in the village boundary. Based on main stream of the village and all types of land use/land cover *i.e.,* agricultural land, forest land, pasture land, residential and industrial area, a micro-watershed (5G1D2b3g) having an area of 602.83 ha was selected for study purpose. (Fig. 2).

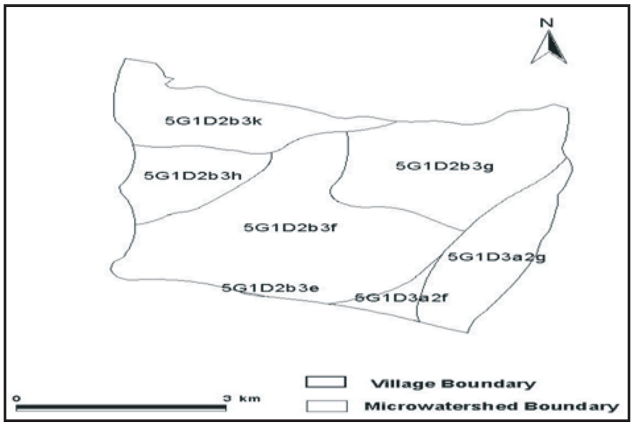

Fig. 2. Selected micro-watershed (5g1d2b3g) with village boundary

Materials Used for Thematic Maps

Satellite Data

Satellite image acquired in January, 2004 from IRS P6 LISS IV sensor, was used for present study. Watershed area superimposed on satellite data is shown in Fig. 3.

Secondary Data

Existing maps, SoI (Survey of India) 1: 50,000 scale Toposheet No. 41k08 and 41k12, Census data and cadastral map of scale 1: 7920 showing individual parcel boundary were used in this study. Transect walk and reconnaissance survey was conducted in watershed area to establish the correctness and cross-checking of visual interpretation.

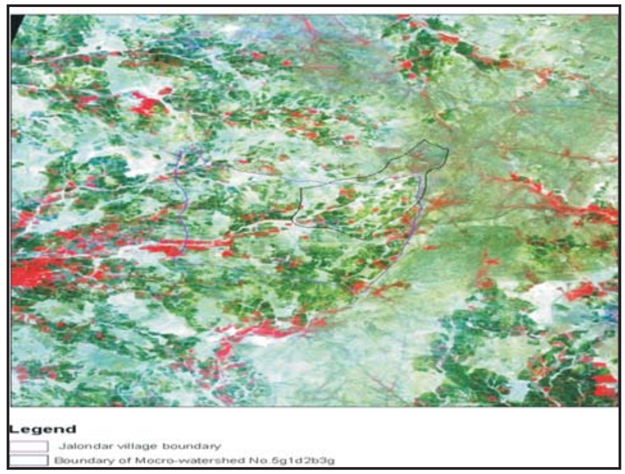

Fig. 3. Village Jalondar and micro-watershed no. 5G1D2b3g on remote sensing image

Softwares

Arc View software was used in the study for preparation of thematic maps while the Environment for Visualizing Images (ENVI) software was used for registration and superimposition of cadastral map with thematic maps.

Generation of Thematic Maps

Thematic maps of soil texture, land use/land cover, drainage pattern, slope, groundwater potential and hydro-geomorphology was generated using micro-watershed boundary, SoI toposheets, satellite image and image processing software Arc View Version 9.1. After scanning of cadastral map using scanner, registration and superimposition of cadastral map on each thematic map was carried out using ENVI 4.0 image processing software.

Rainfall Analysis

The daily rainfall data of 23 years (1980-2002) was collected from Meghal Tidal Control Unit, Chorvad (Dist.-Junagadh, Gujarat). Probability distributions were used for frequency analysis of 23 years maximum one-day and annual rainfall data. The rational method was used to estimate the peak runoff rate while Curve Number method was used to estimate the runoff volume.

3. RESULTS AND DISCUSSION

Frequency Analysis of Rainfall

Among the five selected distributions, Log normal (χ^2 = 0.261) was found best fitted for both the maximum one-day and annual rainfall. Using this fitted distribution, the rainfall at different probability levels was estimated and is presented in Table 1.

Table: 1
Maximum one-day and annual rainfall (mm) at different probability levels

Log-normal distributions	Rainfall (mm) at probability of exceedence (%)						
	10	20	30	40	50	60	70
Max. One-day	330.29	239.85	200.33	154.47	126.47	105.63	77.24
Annual Rainfall	1306.3	1187.9	915.9	822.2	702.00	626.41	545.44

Water Requirement

Domestic water requirement

The total quantity of water required for drinking, cooking, bathing, washing hands and face *etc.* and household sanitary purpose was considered as 112 lit $head^{-1}day^{-1}$ (Rangwala, 1990). The average quantity of water required for animals was taken as 110 lit $head^{-1}day^{-1}$ (Tideman, 2002). The total water requirement for domestic purposes was calculated as 13.82 ha-m including 10% accidental water requirements.

Crop water requirement

The average rainfall of the study area was estimated at 778.05 mm with 50.95% co-efficient of variability. To avoid crop failure in the study area and to get maximum production, water supply was ensured at such critical stage of crop growth in which rainfall was less than water required. The data (Fig. 4) revealed that sowing of *kharif* crops could be done in the 25^{th} or 26^{th} standard week because of 29.01 and 31.59 mm of rainfall at 60% probability level respectively. Based on the availability of water through rainfall occurrence at 60% probability level, irrigation schedule was planned (Oswal and Saxena, 1980). When rainfall was less than the amount of water required, then 5 cm irrigation was planned at that critical stage of the crop growth by surface method of irrigation. After monsoon season, 5 cm depth of irrigation was considered at each critical crop growth stage of each crop. For calculating the water requirement of the study area, 100% area was considered under different crops during *rabi* season whereas during summer season for fodder security purpose, 2024 m^2 area per cultivator under jowar was planned. The conveyance, distribution and application losses were considered as 30% of the net irrigation requirement for the crops during the year for calculating the gross irrigation requirement of the study area (Anonymous, 1994). Average evaporation losses were assumed as 2.7% of the net irrigation requirement (Anonymous, 1994). Seepage losses were not considered in the present study because ultimately

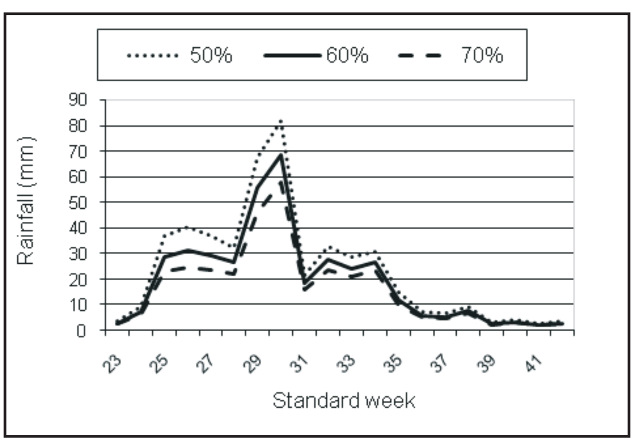

Fig. 4. Standard week wise probable rainfall (mm) at different probability levels

it will contribute to the ground water (Anonymous, 2006). The gross water requirement for agricultural purpose was calculated as 963.22 ha-m.

Total water requirement of study area is the sum of domestic and gross agricultural requirement of water and was calculated as 977.04 ha-m.

Water Availability

The amount of available water from rainfall in the study area at different probability levels is presented in Table 2. The curve number was found as 88.23 using standard Tables given by Ogrosky and Mockus (1957). The maximum retention capacity of the area was computed as 33.88 mm. The runoff from the study area was calculated by subtracting one-day maximum retention capacity of the study area from one-day rainfall for 23 years. The runoff was considered as 30% of total rainfall at 75% probability level from the study area as calculated by Weibull's formula (Subramanya, 2004).

Table: 2
Rain water availability at different probability levels

Sl. No.	Component	Probability of exceedence (%)		
		50	60	70
1	Annual rainfall (mm)	702.00	626.41	545.44
2	Area of village (ha)	1611.63	1611.63	1611.63
3	Total available rainwater (ha-m)	1131.36	1009.54	879.05
4	Water required (ha-m)	977.04	977.04	977.04
5	Runoff available from rainfall (ha-m)	339.41	302.86	263.72
6	Runoff required to conserve (ha-m)	185.09	270.36	361.70
7	Runoff depth required to conserve for gap filling	114.84	167.76	224.43

Thematic Maps

The observations and data obtained from various thematic maps were used for watershed planning.

Land Use/ Land Cover Map

The spatial distribution of land use/land cover of the micro-watershed as interpreted from satellite imagery is presented in Fig. 5. The data revealed that, out of 602.83 ha area of the watershed, 316.68 ha (52.53%) was under cultivation. During *kharif* season, 292.08 ha area was under single cropping system whereas only 243.60 ha area could be cultivated during *kharif* and *rabi* season, which reflects that there was a shortage of water for irrigating these crops. The area under wasteland is 128.77 ha, out of which 79.05 ha is without scrub.

Soil Texture Map

The soil texture thematic map (Fig. 6) reveals that there are two types of soil in the watershed area. The area covered by clay soil and loamy is 75.9 and 24.1%, respectively.

Slope Map

Most of the watershed area (89.83%) was under 0-3% slope (Fig. 7). Only 10.37% watershed area was having 3-

15% slope. The cultivable area having 0-3% slopes needs conservation practices for *in-situ* moisture conservation to increase the agricultural production. The runoff contribution from area having 3-15% slope should have non-erosive velocity; therefore, soil conservation measures such as check dams, small embankments need to be constructed as per the requirement for water harvesting as well as erosion control.

Drainage Pattern Map

The drainage map (Fig. 8) revealed that the drainage pattern of the watershed is dendratic type. It was observed that as order of drainage increase, the discharge increase, the gradient decrease, the velocity increase and channel size increase to accommodate the increase discharge. Based on that, drainage pattern were classified as first order, second order and third order.

Planning of Soil and Water Conservation Measures

Based on land use/land cover, slope, soil texture and soil depth derived from thematic maps, different soil and water conservation measures were suggested as given in Table 3. The designing of these structures was done as per the standard design procedure (Tideman, 2002; Kumar *et al.,* 2011).

Agricultural Land

The contour bunds were proposed on agricultural land. Total height of the bund was computed as 65 cm by

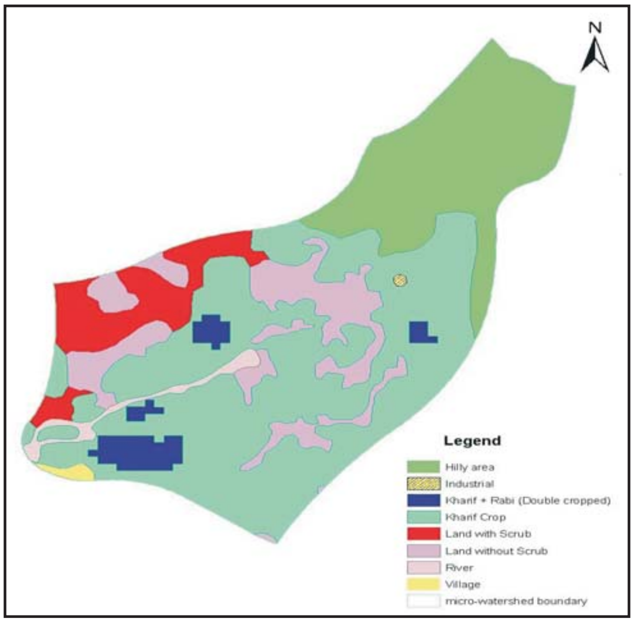

Fig. 5. Land Use/ Land Cover Map

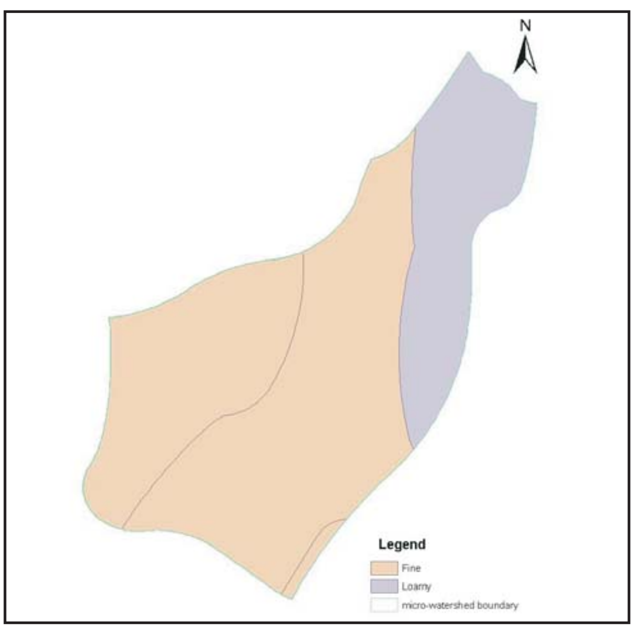

Fig. 6. Soil Texture Map

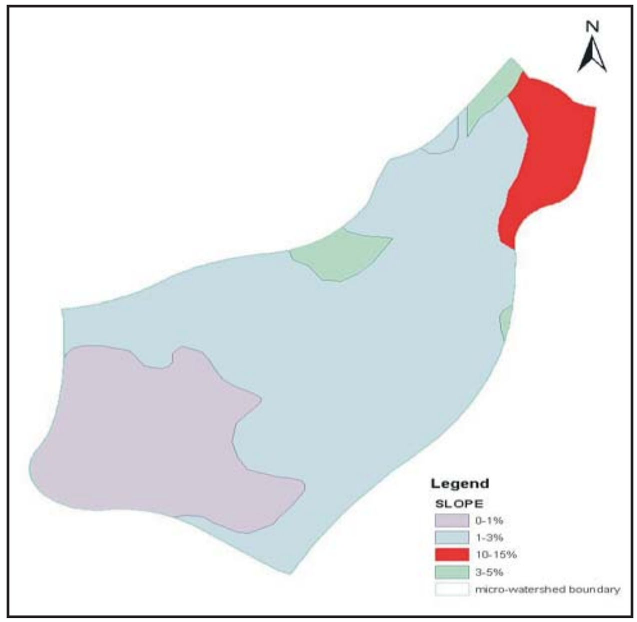

Fig. 7. Land Slope Map

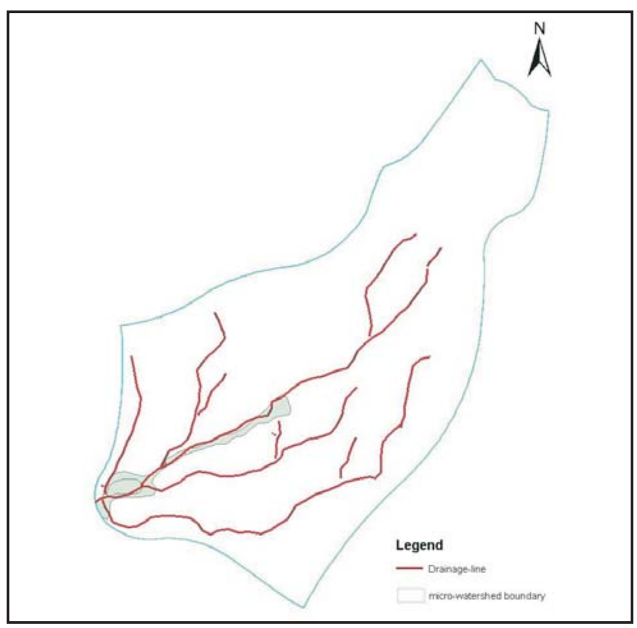

Fig. 8. Drainage Pattern Map

considering depth of impounding water, depth of flow over crest and freeboard as 20, 30 and 15 cm, respectively. The runoff water available from 1 ha area at 60% probability of one day rainfall (105.63 mm) was calculated as 441.40 m^3. Total water storage capacity for 316.67 ha area was calculated as 13.98 day^{-1} at 60% probability.

Wastelands

Staggered and continuous contour trenches were proposed on wastelands with 0 to 5% and wastelands with more than 5% slope steepness, respectively. The horizontal intervals for staggered trenches were taken as 4.5 m and 3 m at 0-3 and 3-5% slope, respectively while horizontal interval for continuous trenches were considered as 4.5 m (Singh *et al.,* 1990). Total water storage capacity of staggered and continuous contour trenches was estimated as 2.82 and 1.89 ha-m day^{-1}, respectively. For fuel security, tree plantation (Neem, Banyan tree, Eucalyptus, Drumstick *etc.*) was suggested on the bunds of staggered and continuous trenches. For fodder security, grasses (marvel and shaniyar) were suggested in the space between two successive lines of trenches.

Drainage Line

Loose rock dam

Loose rock dam was proposed in the first order stream (2942.12 m) of the drainage-line in the upper portion of the catchment having 2% slope, where the average depth and width of gully was 1 and 3-5 m, respectively. Considering the slope of the drainage line, 118 loose boulder dams were proposed in the first order gully. Water storage capacity of one loose boulder structure was estimated to be approximately 25 m^3. Total water storage capacity of loose boulder structures was estimated to be 0.295 ha-m.

Water Harvesting Structures

Rational method was used for computing water yield for 10, 25 and 50 years return period. Peak rate of runoff was estimated to be 46.58, 59.38 and 71.36 cumec for 10, 25 and 50 years return period, respectively. The values of peak rate of runoff were used to design check dam in the micro-watershed.

There are 19 existing check dams in second and third order streams of selected micro-watershed (Fig. 9). Total water storage capacity of these water-harvesting structures was estimated to be 4.85 ha-m. In the drainage line, 7 check dams were proposed at different locations. The total water storage capacity of the check dams was calculated as 1.93 ha-m.

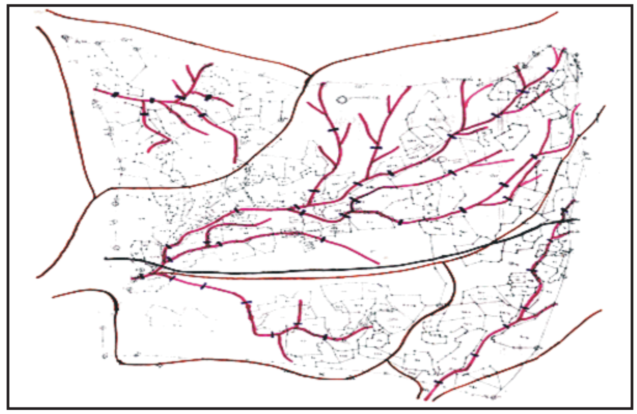

Fig. 9. Location of existing and suggested check dams in cadastral map of village Jalondar

Annual Water Storage Capacity

For calculating annual water storage capacity of contour bund, contour trenches and loose boulder structures, 5 rainy days was considered as calculated by Weibull formula at 60 % probability of rainfall. The annual water storage capacity of different conservation measures in micro-watershed was calculated as 168.70 mm as given in Table 4. The data reveals that the suggested conservation measures are sufficient to meet the demand of water *i.e.,* 167.76 mm at 60% probability of rainfall occurrence.

4. CONCLUSIONS

In the study area, at 60% probability of rainfall, there was a water resource gap of 270.36 ha-m (167.76 mm). Therefore, in order to fill this gap, existing conservation measures are required to be used at full potential along with suggested measures. The study suggests contour bund for agricultural fields, contour trenches for wasted lands, loose boulder check dams for first order stream and water harvesting structures for second and third order streams; in addition, plantation on bunds, trenches and adjacent to check dams are recommended. Hence, cadastral leveling planning proves that in semi arid regions, if micro watersheds are treated as per standard water conservation practices, there is no need to import water from external sources either for domestic, animal husbandry or agricultural purposes.

Table: 3
Suggested soil and water conservation measures

Sl.No.	Land Use/Land Cover	Slope (%)	Soil Texture/Stream Order	Soil Depth	Suggested Measures
1.	Agricultural Land	0-3	Clayey (Medium Black) Loamy (Light Red)	15 cm to 90 cm	Contour Bund
2.	Wasteland - I	0-5	Clayey (Medium Black) Loamy (Light Red)	15 cm to 90 cm	Staggered Contour Trench
3.	Wasteland - II	5-15	Clayey (Medium Black)	15 cm to 30 cm	Continuous Contour Trench
4.	Drainage Line	0 - 1	First Order Stream	_	Loose Rock Dam
5.	Drainage Line	> 1	Second and Third Order Stream	_	Check Dam

Table: 4
Total water storage capacity of the selected micro-watershed

S.No.	Land use/Land cover	Area (ha)	Proposed measures	Storage capacity (ha-m)	Annual storage capacity (ha-m)
1	Agricultural land	316.67	Contour Bund	13.98/day	69.89
2	Waste land - I	230.63	Staggered Trench	2.82/day	14.10
3	Waste land - II	40.42	Continuous Trench	1.89/day	9.45
4	First order stream	0.9	Loose Boulder Dam	0.295/day	1.48
5	Second and third order stream	10.76	Existing Check Dam	4.85	4.85
			Proposed Check Dam	1.93	1.93
6	Village-tal	2.87	-	0	0
7	Small industries	0.58	-	0	0
8	Total	602.83	-	Total	101.70
9	Total depth of conserving water (mm)				168.70

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