Journal of Agrometeorology 10(1) : 27 - 32 (June 2008)

Planning, designing and construction of series of check dams for soil and water conservation in micro-watershed

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ABSTRACT

Planning, design and construction parameters of series of water harvesting structures were presented for 66.75 hectares in micro-watershed. Thematic maps were prepared for planning, design of various types of water harvesting structures in 1:5,000 scale on land use/land cover, soil with drainage status. The slope of the land varies from 0-5 per cent and slight, moderate and serve erosion classes were observed.

The total volume of water storage is 61,200 m^3 at cost of 6.75/1000 liters, which also be estimated to protect 1607 m^3 of productive soil from flowing out of the area. The series of check dam is found suitable for retaining productive soil and also to help in conservation of moisture for horticulture land.

Key word: Micro-watershed, thematic maps, water harvesting structures and conservation of soil and water.

Management of soil and water resources for enhancing horticulture production is of growing concern worldwide and this is especially true for developing countries like India. Efficient management and utilization of these resources are very important to increase the horticulture production and productivity per unit area. One of the principal reasons for the low productivity in horticulture is the progressive deterioration of soil due to erosion. The factors for soil erosion in India are excessive deforestation, overgrazing and faulty practices. Consequently, valuable topsoil is lost and its fertility gets depleted resulting in poor horticulture yield. Soil erosion mainly occurs due to high velocity of runoff flowing over the land surface. It is dependent on land slope, crop cover and rainfall characteristics of the watershed.

The Ministry of Agriculture GOI has identified watershed management as the most rational unit for planning, design and implementation of the programs, dealing with the agriculture as well as horticulture production. Check dams are constructed across the emphereal streams to intercept runoff from catchments and stored it for optimum utilization (Khan, 1992). These structures are suitable where emphereal streams are available in catchments with good runoff producing characteristic and are widely adopted in Gujarat. (Anon., 1988). Only a portion of the rainwater gets stored in the soil profile and excess runoff water needs to be harvested in structures to meet the irrigation requirement of crops and other water needs in the area (Pillai, 1987, Natividad and Wooldridge, 1997). In designing spillways and outlets or waterways, peak rate of runoff value is required; for assessing storage value in earthen dam, tanks and ponds etc. estimates of runoff volume are required. Singh 1987, in their study on conservation structures in catchments of the river valley projects and flood prone river urged the necessity of standardizing the planning and designing of soil and water conservation in India in order to make it cost effective. Narayanan (1962), observed that check dams constructed by local farmers are sometimes either big or smaller than the requirements and are not located at proper place and not designed appropriately.

In horticulture, to increase the fruit production and to meet the flood, fodder and fiber requirements of ever growing population proper planning, designing and construction of check dams for soil and water conservation resources on the watershed basis is desirable.

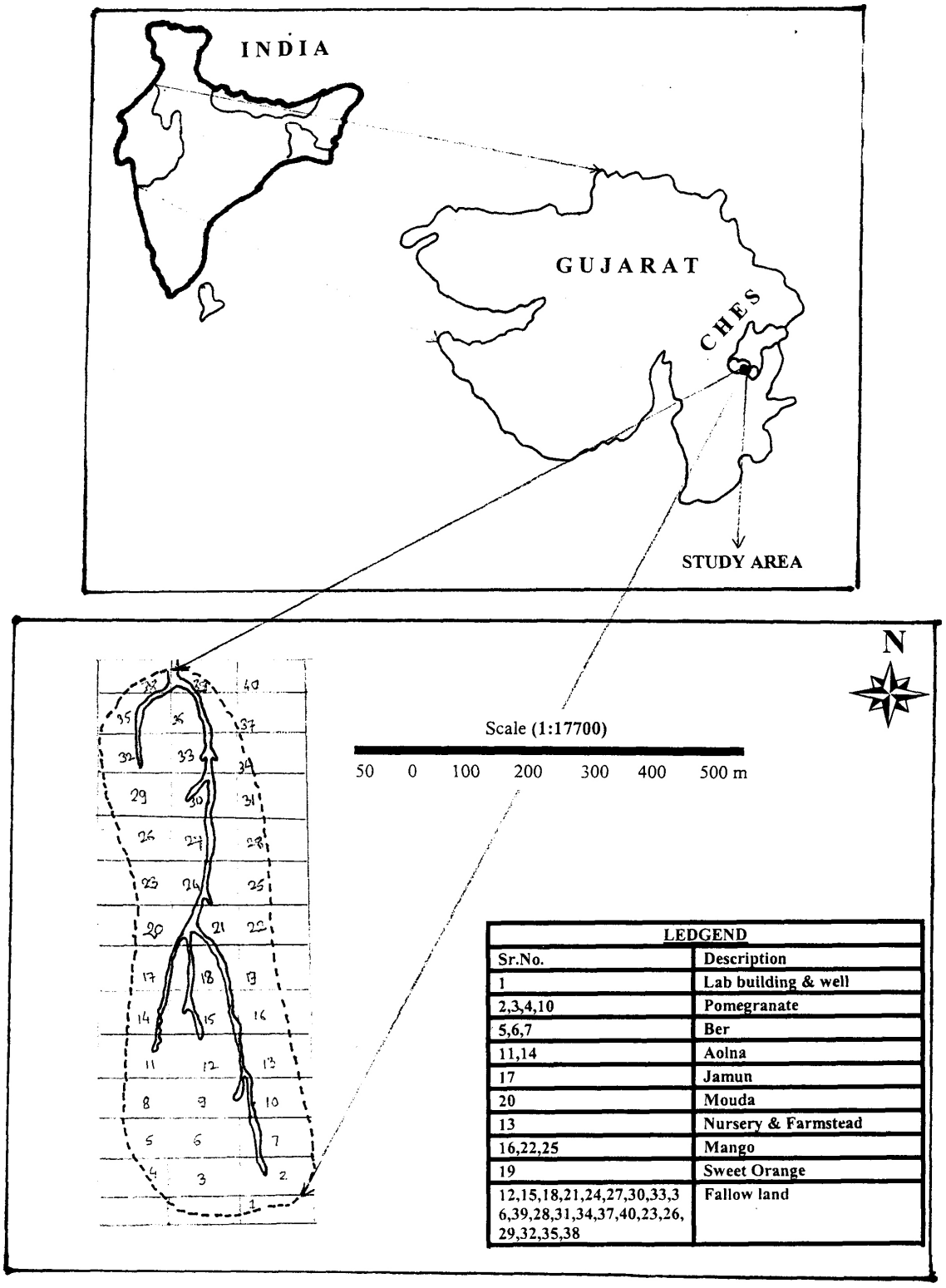

Fig. 1: Location map of the study area.

Table 1: Monthly mean of the weather parameters.

Months	Weather P			
	T_x (°C)	T_n (°C)	R (mm)	E (mm
January	28.2	12.5	2.0	4.1
February	31.2	14.3	0.0	5.6
March	35.7	17.0	0.2	8.0
April	38.6	22.0	1.7	9.2
May	39.6	25.5	7.0	10.5
June	37.1	27.8	142.3	7.8
July	32.0	25.2	307.3	3.8
August	30.7	24.5	265.8	3.7
September	32.4	24.0	108.9	5.7
October	33.3	20.3	22.4	8.1
November	32.0	17.5	9.20	8.8
December	30.0	14.8	6.20	7.6
SD	3.5	5.08	1.27	6.1
CV(%)	10.6	24.9	152.7	38.2

MATERIAL AND METHODS

Location

The study area is bounded by lat 22^0 41'38" N and long $73^0$33'22" E and is located in Central highland of Panchmahals district, Gujarat with total area of 0.667 km^2 . (Fig,1.). The micro-watershed is mostly plane with altitude ranging from 110 m at S/H No.5 to 115 m amsl at Kharashalia Village. It is a part of Ruparail tributaries of Goma river, Mahi basin of Gujarat state having conspicuous physiographic variations comprising undulating plan and basalt tracts. Drainage pattern is mostly dendritic and jointly controlled by parallel drainage pattern at some places. The area has sandy clay loam soil; highly truncated and gently sloping terrain on both sides of river results in quick build up of run off into shallow precipitous tributaries (Ruparail) that drain into the Mahi river. This region is characterized by semi-arid climate with little or no water surplus (Bhattacharjee *et. al.,* 1982).

Climate

The climate of the study area is semi-arid eco-region with well defined summer (March-June), rainy season (July – October) and mild winter (November-February). The mean annual precipitation is 873 mm of which nearly 98 per cent is received during south – west monsoon period (July-October). The mean annual air temperature is 27.5^0 C. The mean air summer temperature is 29^0 C, while mean winter air temperature is 24^0C, (Table1) indicating that the area falls under hyperthermic soil temperature regime.

Physiography

The general topography of the study area is plane and rolling with vertical gully along drainage channels of the watershed. Land slope varies from 0-5 per cent with low drainage density and high drainage frequency. The micro-watershed land use and land cover pattern along with geomorphologic parameters is shown in table,2.

Detailed studies were made to determine land use/ land cover, soil type, drainage pattern, current erosion condition and slope of the micro-watershed. Based on theses data, decisions are made on including excessive meandering of the drainage and wetness in the bed or expected pounding area and hard strata of site for the construction of check dams (temporary / permanent) and recharging well. A number of check dams were planned to arrest erosion and to plug the small gully at appropriate places.

Thematic maps were prepared in 1:5,000 scale on land use/land cover, soil and water resources action plan with drainage network and planning, design and construction of various types of series of water harvesting structures (i.e. ED-Earthen Dam, LBS-Loose Bolder Structure, BWD-Brush Wood Dam, GBSD-

Table 2: Geomorphologic parameters of the micro-watershed.

Sr.No.	Aspects	Parameters	Value
1	Numbers of 1st order stream	N_1	12
2	Numbers of 2nd order stream	N_2	3
3	Numbers of 3rd order stream	N_3	1
4	Length of 1st order stream	L_1	1.645 km
5	Length of 2nd order stream	L_2	0.55 km
6	Length of 3rd order stream	L_3	0.66 km
7	Length of main stream	L_{ms}	0.885 km
8	Perimeter of the basin	L_p	0.6 km
9	Length of centroid	L_{ca}	0.775 km
10	Length of overland flow	L_o	0.153 km
11	Elongation ratio	R_e	0.952
12	Circulatory ratio	R_c	0.67
13	Form factor	R_f	0.265
14	Drainage density	D_d	3.298 km km^{-2}
15	Drainage frequency	D_f	28.23
16	Relief ratio	R_r	0.012
17	Ruggedness number	R_N	0.085
18	Average slope	S_a	0.013
19	Mean elevation of watershed	E	113.5 m (above BM)

Gunny bag sand dam, PCD_1 – Permanent Check Dam-1 and PCD_2 – Permanent Check Dam -2) using survey of India Toposheet No.46F/10, actual ground truth and analysis of collected data.

RESULTS AND DISCUSSION

For the micro-watershed (length-1.654 km and catchments area 66.74 hectares), The hydro-geomorphic features are presented in Table 2. The design peak rate of discharge and storage capacity of each structures (Table 3), indicates that the storage capacity and peak rate of discharge of permanent check dam_2 are higher as compared to others. It is revealed that, the total volume of storage is 61200 m^3 and its total water spread area is 4.55 hectares at a cost of Rs.6.75/1000 liters and is estimated to protect 1607 m^3 of top productive soil from flowing out of the area. The design dimensions of drop spillway at each water harvesting structures are presented in Table, 4.

The analysis of erosion due to rainfall indicated that more than 2.2 cm rainfall storm is erosive. In general 42 per cent of total rain storms cause erosion in this area. The slope and erosion range at each structure indicate that, the slope is more; the rate of erosion is more. In this area, the slope varies from 0-5 per cent with soil erosion of 0-80 Mg ha^{-1} $year^{-1}$. The soil erosion under brush wood dam, gunny bag filled with sand dam and permanent check dam_2 were found to be 40-80 Mg ha^{-1} year due to high slope and poor land use/land cover pattern.

The cost of the storage per cu m (Table, 6) was calculated as Rs. 4.12,4.05,6.72,3.35,9.70 and 10.49 for earthen dam, loose bolder structure, brush wood dam, gunny bag filled with sand dam, permanent check dam_1 and permanent check dam_2, respectively. The series of structures is also used to increase ground water potential and recharging water in downstream side of the well. It can be used as barrier at regular distance in gully and small streams. The tributaries of big streams if provided with a series of structures at a regular interval, then it can help in preventing silting of big dams. Hence, series of water harvesting structures are useful in conservation of water preventing loss of productive soil in this area. The excess rainfall storage due to structures is also useful for irrigation during lean periods. It was found effective for conserving soil, water, protecting the productive soil and regulate the flow of water from horticulture land. These structures are helpful for soil and water conservation, preventing bed scoring and new gully formation in the horticulture land.

Table 3: Peak rate of discharge at each structure through rational formula (Q=CIA/360)

Parameters	ED	LBS	BWD	GBSD	PCD_1	PCD_2
C	0.23	0.23	0.20	0.25	0.20	0.30
I(mm/hr)	90.00	120.0	120.00	120.0	120.00	120.00
A(ha)	12.00	8.0	6.00	8.0	15.00	17.90
T_c(hr)	0.20	0.30	0.20	0.20	0.30	0.40
Q (m^3/sec)	0.84	0.61	0.40	0.66	1.00	1.80
SA(ha)	0.56	0.48	0.32	0.38	1.25	1.56
D(m)	3.10	3.30	2.50	2.8	3.20	3.60
SC(m^3)	6944	6336	3200	4256	18000	22464

(Notation: C-Runoff Coefficient, I-Rainfall Intensity (mm hr^{-1}), A-Area(ha), T_c- Time of Concentration (hr), Q-Peak discharges(m^3/sec), SA-Submerged Area, D- Maximum depth of water & SC – Storage Capacity)

Table 4: Design dimension of drop spillway at various WHS.

Parameters	ED	LBS	BWS
Q(m^3/sec)	0.84	0.61	0.40
L(m)	1.00	1.00	1.00
H(m)	0.70	0.60	0.40
F(m)	0.50	0.50	0.50
C(m)	1.114	1.114	1.114
E(m)	2.70	2.40	1.80
L_B(m)	1.85	1.68	1.172
J(m)	1.40	1.20	0.80
S_1(m)	0.175	0.15	0.10
S_t(m)	0.23	0.20	0.13

(Notation: Q-Peak Discharge, L-Length of weir, h-depth of weir, F-Net drop, C-Correction factors, E- Minimum length of head wall extension, L_B- Length of apron, J-Height of wing wall and side wall junction, S_1-Height of longitudinal sill and S_t-Height of transverse sill)

Table 5: Area under different classes of slope and soil erosion at each structure

Type of Structures	CA (ha)	Slope		Erosion	
		Slope Class	Slope range (%)	Soil Loss Class	Soil Loss ($Mg\ ha^{-1}\ year^{-1}$)
ED	12	Nearly level	0-1	Slight	0-5
LBSD	8	Very gentle	1-3	Moderate	5-10
BWD	6	Gentle	3-5	Severe	40-80
GBSD	8	Gentle	3-5	Severe	40-80
PCD_1	15	Very gentle	1-3	Moderate	5-10
PCD_2	17.74	Gentle	3-5	Severe	40-80

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Table 6: Average cost of construction of various water harvesting structures.

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Received : June 2006; Accepted December 2007

Type of construction	Capacity of the structures (m^3)	Earthwork cost • Rs.	Materials cost Rs.
ED	6944	254835	028315
LBSD	6336	229545	025505
BWD	3200	1937610	021529
GBSD	4256	136125	015125
PCD_1	18000	34941	139764
PCD_2	22464	47164	188656